INDEX

TO THE

EXECUTIVE DOCUMENTS

OF THE

HOUSE OF REPRESENTATIVES

FOR THE

SECOND SESSION OF THE FORTY-SIXTH CONGRESS,

1879-'80.

IN 26 VOLUMES.

VOLUME 6.—Ordnance, No. 1, part 2, volume 3.

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INDEX TO HOUSE EXECUTIVE DOCUMENTS.

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REPORT

OF THE

SECRETARY OF WAR;

BEING PART OF

THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE SECOND SESSION OF THE FORTY-SIXTH CONGRESS.

IN FOUR VOLUMES.

VOLUME III.

WASHINGTON:
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1879.

REPORT

OF THE

CHIEF OF ORDNANCE.

REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 20, 1879.

The Hon. SECRETARY OF WAR:

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1879, with such remarks and recommendations as the interests of this branch of the military service seem to require.

Under the various laws of the United States, the Ordnance Department provides arms and munitions of war for the whole military establishment, and has charge of the armories, arsenals, and other ordnance establishments for their manufacture, repairs, and storage. Thus at the present time the department is providing ordnance and ordnance stores for the sea-coast fortifications, the whole body of the militia, the Military Academy, and the Artillery School, and the Regular Army, in the military establishment, and to the Treasury, Post-Office, and Interior Departments, and the Fish Commission, the Marine Corps, and the thirty colleges authorized by section 1225 Revised Statutes. In addition to this work it is charged with other important duties in connection therewith not now necessary to enumerate.

The fiscal resources and expenditures of the department during the year were as follows, viz:

Amount in the Treasury to the credit of appropriations on June 30, 1878	$100,402 96
Amount in the Treasury not reported to the credit of appropriations on June 30, 1878	19,034 95
Amount in government depositories to the credit of disbursing officers and others on June 30, 1878	161,134 72
Amount of appropriations for the service of the fiscal year ended June 30, 1879	1,410,054 41
Amount refunded to ordnance appropriations in settling accounts during the fiscal year ended June 30, 1879	27,394 40
Gross amount received during the fiscal year ended June 30, 1879, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island, and Pacific Railroad Company; from exchange of powder; from sales of condemned stores; and from all other sources not before mentioned	74,638 30
Total	1,792,659 74

Amount of expenditures during the fiscal year ended June 30, 1879, including expenses attending sales of condemned stores, exchange of powder, &c	$1,443,998 74
Amount deposited in the Treasury during the fiscal year ended June 30, 1879, as proceeds of sales of government property	9,144 71
Amount lapsed in the Treasury from the appropriation "Ordnance material," under act of March 3, 1875, during the fiscal year ended June 30, 1879	203 00
Amount transferred from ordnance appropriations in settling accounts during the fiscal year ended June 30, 1879	394 09
Amount turned in to the "surplus fund" on June 30, 1878, and June 30, 1879	33,149 87
Amount in government depositories to the credit of disbursing officers and others on June 30, 1879	77,845 25
Amount in the Treasury not reported to the credit of appropriations on June 30, 1879	3,075 63
Amount in the Treasury to the credit of appropriations on June 30, 1879	224,848 45
Total	1,792,659 74

STATIONS AND DUTIES.

With few exceptions, the stations and duties of the officers remain the same as reported last year, viz: Two at the Ordnance Office; thirty-four at the arsenals, armory, and powder depots; eight at the ordnance agency, on the Ordnance Board and at the foundries; seven at the different military headquarters and ordnance depots; four at the Military Academy; two under the orders of the honorable Secretary of the Interior, and two on leave of absence (sick). Captains C. E. Dutton and Pitman have, on application of the Secretary of the Interior, been detailed for duty in that department, and Lieutenant Lyle still continues on duty in the Life-Saving Service under the Secretary of the Treasury. Under the operations of existing laws, four officers have been transferred to the department from the line of the Army, after passing satisfactory examinations preliminary thereto.

During the past year death has taken one of our most meritorious officers—Lieutenant-Colonel Treadwell. To abilities of no common order, and to services highly distinguished, he added a pure record and a kindly nature, and his loss is deplored by the entire department.

All of the officers of the department have been busily engaged on the important duties devolved upon them by law, and the results of some of their labors are shown in the many interesting and valuable papers appended.

I append a roster of the corps, with the stations and duties of each officer.

ARSENALS, ARMORIES, AND DEPOTS.

The various duties at our ordnance establishments have been performed in a most satisfactory way, and the moneys appropriated for repairs and improvements have, it is believed, been expended in an eco-

nomical and judicious manner, yet in most instances the money available has been of so small an amount as to preclude anything but the most minor work. I have estimated for the next fiscal year for sums which I consider should be granted to enable me to properly preserve and protect the large public property under the control of the department.

By a reference to the report of the operations carried on at the Rock Island Arsenal it will be seen that the construction of the new buildings has progressed in a satisfactory manner, and with the aid of the new appropriations asked for, the workshops will soon be in a condition to receive their machinery and commence manufacturing to meet the future wants of the country.

The ordnance depots have met the expectations of this office, and have proven to be of great convenience in speedily supplying the troops serving in the field against the hostile Indians. Ample supplies have been collected and placed under the immediate control of the military commanders interested, and by them have been distributed to their commands as occasion has demanded.

An officer of the department is now engaged in examining the various sites offered for the establishment of the new powder depot on the Atlantic coast, and it is presumed that he will soon be able to recommend a suitable location, when steps will be taken to secure sufficient land for the erection of the proper magazines and other buildings for the storage and handling of powder.

I beg to ask the especial attention of the Secretary of War to my estimate for continuing the boring of the artesian well at the Benicia Arsenal to a depth sufficient to determine whether a good supply of palatable water can be procured. The well has now reached a depth of 1,407 feet, and it is thought proper to carry it down 600 feet more. A perusal of the interesting report of the commanding officer of that arsenal (Appendix L) will show what difficulties have been encountered and overcome so far, and what may be expected in the future progress of the work. The many artesian wells on the Pacific coast have been of a depth only sufficient to reach surface water, which is neither constant in quantity nor sufficient in supply. Whether at a depth such as has been reached in other quarters of the globe a full, constant supply can be obtained, is a matter that deeply concerns the manufacturing and agricultural interests of the Pacific coast, and I trust that it will be deemed of sufficient importance to strongly recommend to Congress the desirability of a proper appropriation to demonstrate its success or failure.

A recent official visit to the Benicia Arsenal has impressed me most forcibly with the wants of that national establishment, and the pressing necessity of enlarging and perfecting its manufacturing and storing facilities. Under the careful, economical, and intelligent command of Lieutenant-Colonel McAllister the arsenal has been established on a satisfactory basis, reflecting great credit on his executive and administrative

capacity and professional attainments. The constantly increasing wants of the Pacific coast demand the fostering care on the part of Congress of this, the only manufacturing establishment owned by the United States in that region. I earnestly recommend liberal appropriations for that arsenal.

I have renewed my estimate for an appropriation to purchase a small tract of land adjoining the San Antonio Arsenal. It is absolutely indispensable for the security of the arsenal buildings and the public property stored therein that the government should own this property. Its proximity to the frontier may some day require an increase to its capacity, and this additional ground will be absolutely necessary. Its purchase has been often recommended, and the recommendation has always received a favorable hearing in the Congress, but so far, from some cause, the necessary funds have not been appropriated. Executive Document No. 48, House of Representatives, Forty-second Congress, third session, fully explains the necessity of its early acquirement.

Since my last report, the erection of a building at the proving ground at Sandy Hook, N. J., has been nearly completed, and it is now occupied for the purpose intended, giving good accommodations for the officers and others interested in the important labors at all times in progress. During the present fiscal year the quarters authorized for the superintendent of the grounds will be completed, and the work of grading and leveling the grounds, so far as the limited appropriation will permit, will be carried on. To make the proving ground what it should be requires additional facilities for the storage of powder and other ordnance property, and for the accommodation of the force of mechanics and laborers at all times employed there, and to meet those requirements I have asked for certain sums of money to be expended during the next fiscal year, the detailed necessity for which is set forth in the Book of Estimates, and to which I beg to refer.

ARMAMENT OF FORTIFICATIONS.

An estimate of $950,000 for this purpose has been submitted for the next fiscal year. The limited appropriations for the year 1878–'79 for sea-coast armament have been mainly used in the conversion of 10-inch smooth-bores into 8-inch rifles, and the provision of carriages for the same, and existing contracts are now rapidly approaching completion.

In my report of 1878, I stated that—

> There are but two manufacturing establishments in the country having the facilities and experience necessary for the conversion of guns on the plan adopted. These are the West Point Foundery, Cold Spring, New York, and the South Boston Foundery, Massachusetts, both of which have done foundery work for the government since the commencement of the century. As in all probability we will have to depend on these establishments in the future, the department ought to be in condition to keep them in sufficient orders to preserve the plant and mechanical skill without loss to the companies.

And added—

Irrespective, however, of any consideration of persons or profit the present urgent wants of our forts for armament, and the impossibility of supplying it except by a slow and careful process incompatible with the rush of events in impending war, the economy of working at present prices, besides giving the idle mechanic the privilege of laboring for his bread, all appeal to Congress for a large permanent annual appropriation for this national necessity.

My convictions as to the soundness of the policy of extending governmental support to, and thereby actually keeping in existence, the only establishments in the country organized and fitted to fabricate heavy ordnance, are deepened by a fuller consciousness of how inadequately we are provided in this respect for even common emergencies. This, taken in connection with the fact that our present sea-coast armaments (principally composed of smooth-bores) are almost useless for coping with the heavy artillery of the present, leads me again to urgently recommend that Congress be asked to consider the granting of liberal appropriations for our national defenses, as a matter of the first importance.

The alterations of casemate carriages for 8-inch converted rifles have progressed satisfactorily during the past year, the product enabling us to provide for the guns which have been so far converted, and now available for mounting by the department. In consequence, seventy-five 8-inch rifles ordered for distribution now occupy their emplacements in the forts, or will shortly be in their positions; and, although the number is small and the guns of inadequate power for the more important positions (now occupied principally by smooth-bore guns), yet they provide powerful batteries for our existing casemates of contracted dimensions, and hence the conversion of 10-inch smooth-bores should be continued as rapidly as funds for the purpose are provided.

In this connection, however, it is to be remarked that the provision of guns of much higher powers is a first necessity, and that the expenditures of moneys looking to the provision of the latter should, if practicable, take precedence in the use of funds over all other constructions.

In consequence of these views, the conversion of a 15-inch smooth-bore into an 11-inch rifle—referred to in my report of last year—was undertaken, and the gun is now on the grounds at Sandy Hook undergoing its proof. It has been fired up to date only 33 rounds, and with charges varying from 70 to 85 pounds, and shot weighing from 503 to 506 pounds. The trials are too few, of course, to draw any inferences as to its ultimate endurance; but it may be stated that the gun appears, so far, to be sound in all respects. Its test will be pushed forward to a completion as rapidly as the circumstances attending the proof will admit.

The want of means, and the introducing of some changes in the traverse gear of the chassis of the carriage of the 12-inch rifle, have led to a suspension of the trials with this gun.

The 10-inch rifle, also, has only been fired a few rounds since the last

report, it being thought more important to apply our available means to the test of the 11-inch construction; also to retain it, for the present, for use in the important duty of testing different experimental powders and projectiles.

The important tests of the 8-inch breech-loading rifle, converted from a 10-inch smooth-bore gun, and mentioned as completed and under proof, in my last report, are still in progress, and up to date 202 rounds (190 with full battering charges) have been successfully completed. The endurance so far has proved satisfactory, and no evidences of want of endurance in its special construction have been so far afforded; and we have good grounds for the opinion that it will stand its thorough proof, and establish the fact that we can convert, after this system, our original smooth-bore cast-iron guns into breech-loaders, or produce original breech-loading cannon of the heaviest construction, using in a short time wholly the products of our *own* founderies and other manufacturing establishments.

In my report of 1876 I alluded to the decided advantages to be derived from the use of breech-loading rifles, especially in casemated works. Since then the unfortunate disaster on board of the "Thunderer" (the bursting of a 38-ton M. L. gun by the accidental insertion of two charges—impossible to occur in breech-loaders) and the unexcelled results (in power, accuracy, and successful manipulation) recently attained at Meppen by Herr Krupp in the trials of his breech-loading guns of 70 and 18 tons, have led to the conviction that it is highly probable that the general introduction of breech-loading instead of muzzle-loading cannon in the armaments of Europe—for all heavy ordnance especially—is a mere matter of time. In fact, the high charges now employed—requiring long and large chambers, and, as a sequence to their use, great lengths of bores, so increases the cumbersomeness and inconveniences of the loading apparatus required for muzzle-loaders (besides resulting in exposure to *personnel* and *materiel*) that it is believed it will be decidedly difficult, if not almost impracticable, to operate muzzle-loaders constructed after the *more recent models* with desirable convenience and safety.

These facts have not been lost on the department, and plans are now in its possession looking to the prompt application of the principles of chambering and breech-loading to our present guns, and to new constructions, whenever favorable action on the part of Congress will enable us to undertake the introduction into our service of these recent and most important and decided improvements.

Chambered rifles.—The decided advantages resulting from the introduction of chambers, with increased lengths of bores, for the employment of heavy charges, have been demonstrated by testing a 3-inch rifle chambered and lengthened.

This gun was selected, as it enabled the department, in a prompt and inexpensive manner, to test these novel features. The results, as shown

by the record, were highly satisfactory, and equaling those obtained abroad. An initial velocity of 2,025 feet was reached by the use of 5 pounds 13 ounces of powder with 10.5 pound projectile, the pressures only being 30,000 pounds per square inch.

The highest velocity yet attained with the ordinary 3-inch rifle is, with the highest charge practicable, 3 pounds of powder with 10.5 pound projectile, 1,558 feet, with a pressure of 36,333 pounds per square inch.

The importance of changing our rifling to a more rapid twist, if found by experiments to be practicable, has been recognized for some time by the department, and a 3-inch rifle with a shorter twist than found in the service gun has been prepared and is now under trial with varying weights and lengths of projectiles.

It is believed that the results will be valuable in practically demonstrating the increased capacity and power from the use of a shorter twist, and that they will show the advisability of using a more rapid twist in our heavy calibers.

Breech-loading field rifle.—A wrought-iron field gun was, on plans recommended by Lieutenant-Colonel Crispin, constructor of ordnance, converted, at small expense, into a breech-loading rifle. The results of its trial have been very satisfactory, and the Ordnance Board recommends that a battery of these be made for issue to the service for competitive trials with the muzzle-loaders. As this experiment can be made at trifling expense by converting guns on hand, and enable us to get an expression of opinion from artillery officers as to the relative merits of muzzle and breech-loaders for service, the recommendation, if it meets your approval, will be carried out at the earliest practicable moment.

Powder tests.—During the past year tests have been made of a variety of samples of experimental powders for the 11-inch, 8-inch, 4.5-inch, and 3-inch rifles, and the results obtained are summarized and appended to the firing records of those several guns.

These experiments, though not yet completed, undoubtedly indicate progress in the right direction; and it is confidently believed that ere long we will be enabled to procure powders which will give in these several guns about the initial velocity desired, with moderate and safe pressures. In this connection, it may be said that great credit is due Messrs. Du Pont & Co. for the intelligent manner in which they have interpreted the results of the experiments and promptly met the wants of the department in furnishing samples.

Experimental guns.—Under the act of Congress approved June 6, 1872, appropriating funds for the procurement and tests of experimental rifled ordnance of heavy calibers (to be selected by a board of officers of the United States Army to be appointed by the honorable Secretary of War), the department, under the authority of law, has procured, amongst others, several guns which are now on hand at the proving-ground at

Sandy Hook awaiting trial. These guns are the Woodbridge 10-inch rifle, the Thompson 12-inch breech-loading rifle, the Sutcliffe 9-inch breech-loading rifle, the Lyman multicharge gun, and the Mann 8-inch breech-loading rifle.

The Woodbridge gun has been fired ten rounds; the Thompson two rounds; the Sutcliffe twenty-six rounds; the Mann eleven rounds, and the Multicharge gun three rounds.

The extent of the tests so far made are meager in the extreme, and no evidence of any special importance of the merits of any one of these experimental guns has consequently been obtained. They have been in the possession of the department, awaiting trial, for three or four years, but want of funds to undertake what may be regarded as a suitable proof has prevented the prosecution of the work. They were selected by a board of officers after careful investigation as to their presumed merits as systems of construction (both breech and muzzle-loaders), and have been procured at considerable expense to the government.

In view of the facts that they were provided for experiments and tests, and that none have so far been made to any extent, and, in view of the developments to be expected regarding the numerous questions involved in gun constructions, both muzzle-loading and breech-loading, the interesting and important developments to be made in the furtherance of the solution of the ballistis questions now occupying the attention of the civilized world, and improvements to be developed in powders, projectiles, and systems of rifling, &c., some measures looking to the trial of these guns, and as contemplated by law of June 6, 1872, and to fully test these different inventions (recommended by the board organized under the act), should be instituted by the department. I have accordingly estimated for $117,600, which, if appropriated, will enable me to have the merits of these different systems fully determined.

Machine guns.—The only tests under this head during the current year have been those incident to the trial of a flank defense carriage adapted for the service of the flank defense Hotchkiss revolving cannon.

The necessity of a practical carriage for use with this gun was apparent to the department, and a carriage devised by the constructor of ordnance has been tested with satisfactory results, and recommended for adoption by the Ordnance Board.

MILITIA.

Under the Constitution, "Congress shall have power"—

To provide for calling forth the militia to execute the laws of the Union, suppress insurrections and repel invasions.

To provide for organizing, arming, and disciplining the militia, and for governing such part of them as may be employed in the service of the United States, reserving to the States, respectively, the appointment of the officers, and the authority of training the militia according to the discipline prescribed by Congress.

To make all laws which shall be necessary and proper for carrying into execution

the foregoing powers, and all other powers vested by this Constitution in the Government of the United States, or in any department or officer thereof.

No State shall, without the consent of Congress, * * * keep troops, or ships of war in time of peace, * * * or engage in war, unless actually invaded, or in such imminent danger as will not admit of delay.

For many years there has been a growing feeling throughout the country in favor of a reorganization of our militia system. To perfect our present organization, or to improve it by alteration, requires the action of Congress. That Congress has full power to provide for *organizing* the militia in time of peace, under the above-quoted provisions of the Constitution, there can be no doubt, and Congress has exercised this power in the obsolete and meager laws now on our statute-books; but there has been no practical means provided for enforcing obedience to these laws. Everything is left to the discretion of the individual States. A few of the States have small but well-regulated bodies of troops, while others have none, or, if any, undisciplined, ununiformed and indifferently equipped. It seems to me that the time has come when the subject of raising, arming, and equipping, disciplining, and keeping in readiness for service a part of our militia, should receive the thoughtful attention of Congress.

That a portion of the militia should in a sense be mobilized requires no argument, and this active portion should be distributed equally throughout the country according to population.

By establishing the principle by legal enactment, that Congress will help only those who help themselves, and providing that arms and equipments will not be issued to a State except in proportion to its properly enrolled and organized active militia, and that a per diem for camp services shall be paid to those individuals only who are present in camp, and only for the days that they are present and actually employed, the States and people may be brought to a realizing sense of the necessity for prompt and permanent action in a matter so vital to the military power of the nation. The general government, under the law of 1808, now supplies arms and equipments to the militia of the States, and there is no reason why their issue should not be made dependent on acts to be performed by the States, such as the organization and discipline of a certain portion of the militia.

I have, therefore, to recommend that provision be made by law for organizing, arming, and disciplining a militia force of two hundred thousand men, distributed among the States in the proportion of about seven hundred men to each Congressional district and Territory, and the District of Columbia.

To make this practicable will require large annual appropriations, appropriations that must be permanent, at least for a few years, to give a trial to the scheme.

In the first place, there should be an annual appropriation of $1,000,000 for arms and equipments, which would give about $3,000 for the troops

in each Congressional district. The necessity for this increase of the annual appropriation for arming and equipping the militia is so well understood and appreciated, has been so often referred to at length in official reports from this office and the War Department, that no lengthy discussion is called for.

The aggregate strength of the militia of the United States, as taken from the last Army Register, is as follows:

Organized	113,873
Unorganized	3,822,114

and only $200,000 is annually appropriated for their arms and equipments. With our small standing army, the country must recruit its fighting force from the people on the instant upon the breaking out of war. The soldiers who fought our recent battles will soon pass from the scene, or become too old for active service, and most of the experience of the war will be lost to the country, with the actors in their graves. Half a generation has passed away since the close of that mighty struggle. In a very few years dependence will have to be placed on the raw recruit; and while the experience of the bivouac and battle cannot be acquired in peace and in the quiet avocations of ordinary life, much can be effected by placing in the hands of the young men the arms they may have to use in war, and encouraging that military spirit which alone can make material for soldiers. The distribution of arms to the militia is a vital element in this regard, and the want of a large standing army must be compensated by a well-organized, well-armed, and well-disciplined militia.

In the second place, there should be an annual appropriation of $4,000,000 for the expenses of an annual encampment—the payment to each militiaman a per diem for each day's service while actually in camp, &c. In this manner the benefits to be derived from this appropriation would be strictly confined to those States and to those individuals complying with the requirements of the general government.

The laws upon our statute-books need a thorough revision, after a calm and most careful consideration of all the various elements that enter as factors. The supervision and control to be exercised by the general government must be fully and definitely set forth, as definitely and concisely for a time of peace as for a time of war, and this degree of supervision once determined should be fixed by such enactments as will secure the most beneficial results to the United States, the States, and the militiamen. All are interested in this, in different degrees, perhaps, but none more so than the citizen, who may, at a moment's notice, be called upon to assume the functions of a soldier. I may be pardoned for suggesting, in a few general remarks, what I consider primarily necessary legislation.

1st. A permanent annual appropriation of one million dollars for arming and equipping the militia, organized as proposed.

2d. A permanent annual appropriation of four million dollars for a

per diem of one dollar per man per day, for every day he is present and on duty at the encampment. The encampment to continue twenty days in each year.

3d. The militia should be armed and provided with the same munitions of war as is the Regular Army, so far as the stores furnished by the United States are concerned. The necessity of this is obvious to all, but to none more so than to the veterans of the late war on both sides. It should be understood by the States and the militiamen that the arms and equipments furnished to them do not cease to be the property of the United States, and they should be properly accounted for to the Chief of Ordnance U. S. Army in a manner similar to that in vogue in the Regular Army; and, being the property of the United States, the general government should make the necessary repairs, and should withdraw them when worn out or obsolete, supplying those of later patterns, thus keeping the armament in a continual state of efficiency.

4th. There should be a well-devised system of inspection instituted and administered by the War Department, without which the efficiency of the militia establishment can never be known nor ever be improved. To do this the most competent men should be selected as inspectors, clothed with high rank, certainly not less than that of colonel, and invested with the powers that now appertain to inspectors in the Regular Army. They should be sufficient in numbers to make an annual inspection of the militia of each State and Territory, reporting, in detail, the result to the Secretary of War, and a copy thereof to the governor of the State or Territory interested. Some of these inspectors should be taken from the Regular Army, but the majority from the competent officers of the late war who served on either side, and this corps of inspectors might well be clothed with power, under the Secretary of War, to make such general regulations as are necessary to an uniform dress, drill, and discipline throughout the whole body of our citizen soldiery.

5th. Each State should be obliged to maintain one or more suitable rifle-ranges, and perhaps to offer suitable prizes to incite a proper emulation in target practice, and there should be an officer of high rank in the militia of each State or Territory who should be in charge of such practice.

6th. When the exigencies of the regular service will permit, officers of the Regular Army should be allowed to accept commissions in the militia, without detriment to their regular commissions, upon the application of the governors, and for such times as may be determined upon.

7th. One of the most valuable means of increasing the efficiency of the militia is by the dissemination of knowledge through a military education of the youth of the country. To a certain extent this has been provided for by United States laws; but the laws, as they stand, can be improved, and a system which is undoubtedly good, so far as it goes, be made one that in a few years will furnish a large number of well-educated soldiers, capable of entering upon commands and successfully administering them.

Section 1225 Revised Statutes, as amended by act of July 5, 1876, authorizes the issue of arms, artillery, &c., to colleges where an officer of the Regular Army has been detailed, the number not to exceed thirty, &c. This law calls for material modifications. There should be more permanency in the detail and in the institution that is to receive these benefits. A college that is to be provided with an officer and arms should be specially *designated by the legislature of the State interested*, and service at a college ought not to be optional, but be considered a military duty to which all officers are liable. Governmental supervision and inspection of these colleges as regards military training, discipline, and study, should be a condition attached to the acceptance of the liberality of the general government. The providing of officers and arms makes these colleges, in a sense, a portion, and a very important portion, of the military establishment, because of the direct influence they must exercise over the efficiency of the militia, supplying, as they will from year to year, a number of competent instructors in all that is necessary to make men good soldiers.

By liberal appropriations and some such provisions of law, strictly enjoined and enforced, an active militia of 200,000 men could be kept in hand as a reserve force ready for any emergency, either domestic or foreign. While taking them from their daily avocations for a very limited period during their annual encampment, the daily allowance, though small, would partially compensate them for loss and time. It would give us a large force, supplementing our small Regular Army, always at call, and representing every portion of the country and every characteristic of our varied nationality. It would instil a military spirit throughout the country and keep alive the traditions of the past.

National Reserve.—The proper organization for an armed force in time of peace is its organization for war. A simple expansion can be readily made on the eve of a conflict, but a novel organization at such an epoch is fraught with disaster. Our experience as a nation clearly shows that, not on the militia but on our volunteers has the country depended in years of trial. Would it not be wise in any legislation for the establishment of this force to which reference is made, to break loose from the theories of the past, and empower the President in time of peace to organize a *National Reserve*, under the constitutional power "*to raise and support armies*," on the plan indicated above? Should not State rights and prejudices yield to the necessities that our wars have proved to be imperative? It would be only extending into a national condition what is successfully practised in some of the States, where uniformed volunteer organizations take the place of the ordinary militia. While admitting that the subject is environed by conflicting views of constitutional questions, and by the powerful influences of sectional and individual prejudices, I am satisfied that the laws could be so framed as to guard all individual and State rights from Executive encroachments. The force could by law be localized in proportion to population, camped out

for a limited period annually in their respective localities, and be paid out of the public treasury. In the interest of the public good and the public safety, the subject deserves the careful consideration of Congress.

The act approved March 3, 1875, provides that, under certain conditions, credits are to be given to the several States and Territories for the sums charged to them respectively for arms, &c., which were issued to them between January 1, 1861, and April 9, 1865, and charged against their quotas under the law for arming and equipping the militia. It is made the duty of the Secretary of War to refuse a credit "if he shall find that any of said arms or ordnance stores have been sold," &c. At the close of the war some of the States, through inadvertence, or a wrong interpretation of the laws relating thereto, sold portions of the arms, &c., in their possession, realizing but a portion of the values charged against them on the books of this office. The arms ought not, in my opinion, to have been charged to the States on their quotas, but should have been accounted for as issues to the Army, and the loss of values should have fallen on the United States. In my opinion these charges against individual States ought to be removed, and that the spirit of the law of 1875 be extended, so as to permit credits to be given States for the difference between the prices charged and the prices realized from sale. I respectfully recommend a modification of the act of March 3, 1875, in this regard.

SMALL-ARMS.

During the last fiscal year there were manufactured at the National Armory 20,005 Springfield rifles, and under the law authorizing it, 1,000 of the experimental Hotchkiss magazine rifles. The former have been produced at a much less cost than heretofore, owing to the increased number manufactured and the improvement of the plant employed, and as there is now available a larger appropriation than usual for the present year, it is confidently expected that the cost will yet be further reduced in the future. We had in store on July 1, 1879, only 22,073 rifles and 5,406 carbines at the armory and arsenals, a wretchedly small number considering the wants of the present and the calls that may be made in the future.

The Hotchkiss arms are now in the hands of the Regular Army for trial in actual service, and upon the reports to be made bi-monthly will depend any recommendations for the supply to be hereafter manufactured. But whether this magazine gun is to be the arm of the future or not, it is not safe to delay providing an ample supply of the Springfield rifles, and for that purpose I have asked for the next fiscal year an appropriation of $900,000, which amount should be given in the interests of economy and for the national defense. Last year in my annual report I had the honor to remark upon this matter as follows, viz:

The necessity for an accumulation of arms of the latest pattern has been so often discussed, has received such practical application on the part of other countries, that a further reference to it in this report would be a work of supererogation. The moral

effect of a large supply of arms in readiness for use is always entirely disregarded in the discussion of the subject. To be prepared for immediate hostilities is a quiet power, which must enter largely as an important factor in the determination of international questions that may or may not lead to war, and, as such power, it is worth all the money expended in its production. The argument so frequently used, that the gun of to-day will probably be superseded by a superior invention a few years hence, and the expense of to-day be money thrown away, might be used with equal force and pertinence respecting any article of manufacture whatever. But the present approved arm cannot be rendered worthless by the introduction of an improved weapon, because as long as small-arms are fired from the shoulder and the propelling force is gunpowder, the caliber of gun and dimensions of cartridge, now regulation, will not be changed, and the improvement will only consist in more rapid manipulation and increased rapidity of fire. As a case exactly in point, the Board on Magazine Guns has recommended a gun for trial in the hands of troops that is an improvement on the present Springfield arm only in its ability to empty its magazine of cartridges in one-half the time that the same number of shots could be fired by the latter. Used as an ordinary breech loader, its advantages, if any, are not material or worth consideration, and yet its use as a single breech-loader will be its normal condition, the increased rapidity of the magazine-feeding being reserved for great emergencies. Such a gun, if approved and adopted, in a few years, will not render the Springfields that may be on hand worthless. I therefore hope that Congress may be liberal in its appropriation.

And, in 1877, I said:

Believing that such a country as this, with its great natural resources, abundant wealth an exposed frontier of many thousands of miles, with a shore-line of as many thousand more, should, as a measure of ordinary safety, have always in store not less than half a million of the best and most efficient arms, the manufacture of one-tenth that number during the next year seems so necessary as to call for no argument. It may be true that our policy is peace. If so now, it has been so for a century, and yet during that short period in the existence of the nation we have had not only countless wars with the Indian tribes, but wars with the nations contiguous to our boundary north and south, and the great war of the rebellion. Is it to be expected that a continuance of such a peace policy will, in the present century of the country's life, be more successful in keeping us free from a fair proportion of conflicts in which peace can only be maintained at the sacrifice of men and means? The experience of the most enlightened nations in the past, the gigantic struggle now being waged on the continent, that may ere its close involve other powers and subject all Europe to the horrors of war, prove how far we are yet from a realization of a peace that will last longer than time enough to prepare for a new conflict. If old-established communities, with the cumulative wisdom and experience of centuries to guide them, seem to exist only under the protection of armies, is it to be expected—with a record of our wars during the past century before us—that the United States, almost the youngest in the family of nations, can enjoy a future different from theirs? To be prepared for war is one of the most effective means of preserving peace. Such preparations, to be efficient and complete, must, however, be made at leisure, with all the skill, experience, and means of which we are capable. In making them, time is an element not to be ignored or despised. The progress in invention and of the mechanic arts must be consulted and kept in view in the work of preparation, because the approved articles of the past may have become the mere stepping-stone to the perfected improvement of the present. What fifteen years ago was deemed a perfect musket is now classed as obsolete with hardly a marketable value, and that marvel of mechanism of to-day, the breech-loading rifle, must soon make room for a still greater marvel in simplicity and effectiveness. In our preparations, we must keep abreast of the progress of the age. Get the best of to-day, with the certainty that it must yield to the best of to-morrow. And it is this unceasing, ever-changing, still improving march that enforces constant and unremitting study, and labor, and change, and improvement on the part of governments the

world over, that they may be thoroughly prepared in the day of trial, not with the obsolete appliances of a past age, but with the perfected mechanism of the present. This constant change of model and pattern involves all countries in great expense in fact, in never-ending drafts on their exchequers. But unless a grand council of the nations should decide and fix on the kind, character, and quality of the weapons that are to be used in war, there is but one unerring, unfailing guide to the character of an armament, and that is that it shall be equal, and if possible superior, to that of all others. This entails the constant expenditure of large sums; but such expenditures are more than repaid by the first victory that prevents the capture of a capital or the desolation of a district. At any rate, there is no way known to the world to avoid such a course of procedure, and the necessities of modern warfare demand a thoroughness and completeness in the preparations that no country can neglect.

It is in this view that a large appropriation for the manufacture of arms at the National Armory is deemed imperative. The rifle issued to the Army and the militia compares favorably with the best breech-loader either here or abroad. It is an arm that may not be superseded for many years to come, and if it be obliged to yield to one of superior merit, the effect will not be to render it obsolete, but to make it secondary to one using the same cartridge but having greater rapidity of fire, so that the present single breech-loader will always be a powerful weapon, even when compared with the possible magazine-gun of the future. We cannot be wrong in laying up a reasonable supply of these, therefore, especially as the magazine-gun that may some day be adopted for Army service may require years of invention and improvements to reach that degree of simplicity in its mechanical arrangements necessary to render it suitable for the soldier.

I can only reiterate these views, and express the hope that the wisdom of Congress will grant what we so urgently require.

TARGET PRACTICE.

I have made an estimate for the smallest amount of money which, in my judgment, will be needed to provide ammunition for the use of the service, viz, $200,000. To make our soldiers good marksmen, an ample supply of ammunition must be provided, and this cannot be done unless sufficient money is annually appropriated.

The amount asked for will provide between 7,000,000 and 8,000,000 cartridges, and if all should be expended in target practice it would not give each soldier over 400 cartridges for the year, certainly a very small number when the importance of the subject is considered. But, as a matter of fact, a large part of this quantity is expended for other purposes, in battle, scouting, escort duty, drills, and occasions of ceremony, so that the soldier can hardly expect to fire over 25 rounds per month. The great interest which has sprung up within the last four years in the Army in regard to target practice has not been fostered to the extent it should have been, owing to the lack of funds to procure a sufficient supply of ammunition, and perhaps a well digested system of target practice and the necessary appliances.

By the distribution to the service of a text-book on rifle firing, prepared by your order under my direction by Colonel Laidley, of this department, a system has been adopted which, though undoubtedly susceptible of improvement in future will, with the necessary appropriations for cartridges, enable the soldier to perfect himself as a marks-

man, and to develop to their fullest extent the many excellent qualities of the Springfield rifle.

TEST OF METALS.

The department has now in its possession, set up at the Watertown Arsenal, the finest machine in the world for testing the strength of metals and other materials, and I have asked for a small annual appropriation to enable it to be used. This machine was authorized by Congress and constructed under the immediate supervision of the late United States board to test iron, steel, &c. Valuable results have already been obtained from its limited use, under circumstances very unfavorable, and it is suggested that a wise policy and a just appreciation of the advantages to inure to the various industries of the country will prompt the Congress to grant the small amount of money necessary to develop its capacities.

The work already accomplished has enlisted the active sympathy or scientific men of all classes, and metal manufacturers and users, who have not limited their expressions of approval, but have supplemented them with funds to finish work which was commenced but could not be finished owing to the failure of Congress to appropriate the wished-for money.

From what is known of the wants of officers having charge of government constructions, the lack of definite information on the part of civil engineers, architects, and mechanical engineers throughout the country, and their utter inability to obtain correct data on which to base their calculations, for the need of which large sums have annually to be expended in order that the errors made may be on the side of safety, there is no purpose for which an appropriation could be granted which would yield so large and immediate a return in the way of money absolutely saved as a grant for working this machine and publishing the results obtained, and in the correctness of this opinion I am confident that I will be supported by the whole body of scientific men and manufacturers of metals of superior quality throughout the land.

EQUIPMENT BOARD.

Upon my request a board of officers from the line of the Army was constituted by the Secretary of War to consider the subject of bayonets and intrenching tools. This board was in session nearly four months, and the result of its labors has been published to the Army. As rapidly as possible those of its recommendations which have been approved by the Secretary, and which relate to the stores provided by the Ordnance Department, will be carried out.

INDIAN RIFLES.

As much has been said in official reports and in the public prints respecting the quality of arms used by our Indian tribes, and their great

superiority to the arms in the hands of our troops, in accuracy and range, I inclose a report made at the National Armory, on a number of Indian guns sent to me from the field. I am willing to rest the reputation of the Springfield rifle and carbine on the facts developed in the trial, and recorded in this report. Not even such an admirable weapon as the Springfield rifle can be expected to give satisfaction to every officer and soldier, but it is my firm belief that it comes very near it.

SPRINGFIELD AND PEABODY-MARTINI RIFLES.

In this connection I desire to invite attention to the inclosed report on certain comparisons instituted between the Springfield and Peabody-Martini rifles. These trials were made to show whether the latter was so far superior to the former as was intimated by letter-writers during and after the siege of Plevna in the Russo-Turkish war.

That the ultimate range of the Peabody should be greater was conceded on the simple fact that the charge of powder used was 15½ grains greater, and the bullet 75. grains heavier, than the charge of powder and bullet of the Springfield. The trial, however, showed for the Springfield "superior accuracy," "accompanied with more power than is required to disable a man at ranges at which it is practically impossible for a marksman to hit so small an object." "At ranges of 1,000 yards and upward, the trajectory of the Peabody is slightly flatter, but at shorter ranges—those at which a rifle will ordinarily be fired in service—the trajectory of the Springfield is the flatter, owing to its higher velocity." At 1,669 yards—the longest range in the proving ground—the Springfield hit the target—8′ × 12′—3 times out of 10, while the Peabody was fired 60 rounds to hit the target the same number of times. The Army should be satisfied with such a record. I have directed experiments to be made with the Springfield rifle up to 2,500 yards, and anticipate excellent results.

MULTIBALL CARTRIDGES.

I append a series of reports on the multiball cartridge for revolver. For use in the rifle and carbine, it has not been received with favor, the reports from the field being almost unanimously against it.

Its efficiency as a revolver cartridge will depend on its results at very short ranges—certainly within 25 yards—and on the extent of its scattering. I quote from a report of Captain Greer, Ordnance Department, a most capable and experienced officer and experimenter, made June 7, last:

> With regard to dispersion of fire, which is the true *raison d'être* of these cartridges, an inspection of the tables shows that at short ranges there is none at all, the bullet holes of each shot nearly coinciding. At longer ranges—75 to 100 yards—there is a considerable dispersion of balls; but they have too little power to do much execution.

The department will continue its endeavors to adapt this cartridge to the revolver, and it may be that some simple change in its arrangement and form may fulfill the conditions necessary to make it a success.

CLERICAL FORCE.

In compliance with your instructions, I have omitted in my annual estimate to ask for additional clerks, but I may be pardoned in representing the inadequacy of the force now by law allowed in this office. For the fiscal year ending June 30, 1876, there were allowed, besides the chief clerk, *three* clerks of class four, *three* of class three, *three* of class two, *eight* of class one, *one* messenger, *one* laborer, and *eight* enlisted men, a total of twenty-eight, and in grades and number these were not more than sufficient to meet the wants of the office. Since then the current work of this office has materially increased and is increasing annually, while the clerical force has been decreased. As a consequence, much important work is now, and has been for several years, running behind hand, much to the inconvenience and detriment of the public service, and not unfrequently to the hardship of individuals. I hope that, at the proper time, you will see fit to ask Congress to restore the clerical organization to its former grading.

The following statement will give some idea of the magnitude of the work of this office during the past year:

Number of cash and property returns of all kinds examined	7,192
Number remaining unexamined on account of insufficient clerical force	4,456
Letters and other papers received, briefed, and entered upon the records of the office	15,494
Letters, orders, and indorsements written and sent out	24,094
Number of blanks, public documents, &c., prepared and distributed	35,022

I have the honor to submit the following papers, heretofore referred to:

Appendix A.—Statement of principal articles procured by purchase and fabrication at the arsenals during the year ended June 30, 1879.

Appendix B.—Statement of ordnance, ordnance-stores, &c., issued to the military establishment, exclusive of the militia, during the year ended June 30, 1879.

Appendix C.—Apportionment for the fiscal year ended June 30, 1879, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667 Revised Statutes.

Appendix D.—Statement of ordnance, ordnance-stores, &c., distributed to the militia from July 1, 1878, to June 30, 1879, under section 1667 Revised Statutes.

Appendix E.—Statement of ordnance, ordnance-stores, &c., distributed to colleges from July 1, 1878, to June 30, 1879, under section 1225 Revised Statutes.

Appendix F.—Statement of ordnance-stores, &c., distributed to the Territories and States bordering thereon, from July 1, 1878, to June 30, 1879, under the joint resolutions of July 3, 1876; March 3, 1877; March 9 and June 7, 1878.

Appendix G.—Statement of ordnance and ordnance-stores, &c., issued to the executive departments under the provisions of the act of March 3, 1879.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

Lieut. Col. S. Crispin, Ordnance Department.

Appendix H.—Construction of the 11-inch M. L. rifle, converted from a 15-inch S. B. Rodman gun.

*H*¹.—Construction of a 3-inch B. L. rifle.

*H*².—Construction of a 3.16-inch M. L. rifle, *chambered.*

*H*³.—Construction of a 3.16-inch M. L. rifle, *rapid twist.*

*H*⁴.—Gas checks for B. L. rifles.

*H*⁵.—Alteration in 12-inch rifle-carriage.

*H*⁶.—Proposed chambered rifle, 4.50-inch caliber.

*H*⁷.—Report on experimental cannon-powders, Capt. C. S. Smith, Ordnance Department.

REPORTS OF THE ORDNANCE BOARD.

Lieut. Col. S. Crispin and Lieut. Col. T. G. Baylor, Ordnance Department; Capt. F. H. Phipps, recorder.

Appendix I.—Gunpowders.

*I*¹.—Progress report on powders for 4.50-inch rifle.

*I*².—Progress report on powders for 8-inch rifle.

*I*³.—Progress report on 3.50-inch Deane bronze gun.

*I*⁴.—Hotchkiss revolving cannon, caliber 1.5-inch.

*I*⁵.—Flank defense carriage for Hotchkiss revolving cannon.

*I*⁶.—Relative destructive effects of different Hotchkiss projectiles.

*I*⁷.—Report on Hotchkiss revolving cannon (light field model), cal. 1.50-inch.

*I*⁸.—Progress report on 3-inch B. L. rifle.

*I*⁹.—Progress report on 3.17-inch M. L. rifle, chambered.

*I*¹⁰.—Progress report on 8-inch B. L. rifle.

*I*¹¹.—Progress report on 11-inch M. L. rifle, converted from a 15-inch S. B. Rodman gun.

*I*¹².—Reports on a Gatling gun, caliber .45-inch, English model, having a new pointing apparatus.

*I*¹³.—Report on multiball cartridges for Gatling gun.

MISCELLANEOUS.

Appendix K.—Annual report of the principal operations at the Rock Island Arsenal, 1879, Maj. D. W. Flagler, Ordnance Department, commanding.

Appendix L.—Progress report upon the artesian well at the Benicia Arsenal, 1879, Lieut. Col. J. McAllister, Ordnance Department, commanding.

Appendix M.—Measurement of powder pressures in cannon by compression of oil, Dr. W. E. Woodbridge.

Appendix N.—Trajectories of army revolvers, Capt. J. E. Greer, Ordnance Department.

Appendix O.—Trajectories of the Springfield and Peabody-Martini rifles, Capt. J. E. Greer, Ordnance Department.

Appendix P.—Experiments with small arms—space between bullet and powder, Capt. J. E. Greer, Ordnance Department.

Appendix Q.—Action of sea-water on brass cartridges, Capt. J. E. Greer, Ordnance Department.

Appendix R.—Report on the manufacture of certain life-saving guns, Lieut. C. W. Whipple, Ordnance Department.

Appendix S.—Description of the Lyle-Emery grapple-shot, Lieut. D. A. Lyle, Ordnance Department.

Appendix T.—Description of the Laidley cavalry forge, Col. T. T. S. Laidley, Ordnance Department.

Appendix U.—Swollen barrels in service rifles, Capt. J. E. Greer, Ordnance Department.

Appendix V.—Reports on Indian arms. Capt. J. E. Greer and Lieuts. D. A. Lyle and R. Birnie, jr., Ordnance Department, and Master Machinist S. W. Porter, National Armory.

Appendix W.—Reports on multiball cartridges for small arms. Maj. J. M. Whittemore, Capts. E. M. Wright and J. E. Greer, and Lieuts. R. Birnie, jr., and C. C. Morrison, Ordnance Department.

Appendix X.—Report on range-finders, Capt. F. H. Phipps, Ordnance Department.

Appendix Y.—Showing stations and duties of the officers of the Ordnance Department on the 1st of October, 1879.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,

Brigadier-General, Chief of Ordnance.

APPENDIX A.

Statement of principal articles procured by fabrication at the arsenals and by purchase during the year ended June 30, 1879.

CLASS I.

1 Gatling gun, caliber 1 inch, 10 barrels, long.
14 Gatling guns, caliber .45, 10 barrels, long.
10 Hotchkiss mountain guns, caliber 1.65 inch.
4 Hotchkiss revolving guns, caliber 1.5 inch.
10 Lowell battery guns, caliber .45.
24 coiled wrought-iron tubes for 8-inch converted rifles.

CLASS II.

1 carriage and limber for Gatling gun, caliber 1 inch.
33 carriages and limbers for Gatling guns, caliber .45.
3 carriages and limbers for Hotchkiss revolving guns, caliber 1.5 inch.
10 carriages for Hotchkiss mountain guns, caliber 1.65 inches.
53 carriages and chassis for 8-inch converted guns, fitted with recoil checks.
200 gun carriages for life-saving service.
1 carriage and limber for caliber .45 Lowell battery gun.
4 carts for caliber .45 Gatling guns.
10 cavalry forges, Laidley's.

CLASS III.

125 buckets, various.
30 feed cases for caliber 1-inch Gatling gun.
1,000 feed cases for caliber .45 Gatling guns.
500 feed tubes for Lowell battery gun.
32 gun covers, various.
42 handspikes, various.
200 gunner's levels for life-saving service.
386 manœuvering bars, various.
38 sets artillery harness.
200 lanyards for life-saving service.
400 powder measures.
400 priming wires.
427 quoins, various.
7 pack-saddles for Hotchkiss mountain carriages.
212 sponge covers, various.
281 sponges and rammers, various.
54 tompions, various.
75 vent-pieces.

CLASSES IV AND V.

60 3-inch Butler shot.
50 12-pounder shot, strapped and fixed.

819 8-inch Butler shot.
20 8-inch Eureka shot.
20 8-inch Dana shot.
60 10-inch Butler shot.
10 11-inch Butler shot.
25 12.25-inch Butler shot.
820 3-inch shells.
9 3-inch Eureka shells.
10 8-inch Butler shells.
10 11-inch Butler shells.
44 4.5-inch case shot, experimental.
4 4.5-inch canister, experimental.
1,000 ball cartridges for 1-inch Gatling gun.
1,000 canisters for 1-inch Gatling gun.
2,000 1.5-inch Hotchkiss shells.
6,500 1.65-inch Hotchkiss shells.

Class VI.

500 Hotchkiss magazine carbines, caliber .45.
500 Hotchkiss magazine rifles, caliber .45.
1 Hotchkiss magazine Navy rifle, caliber .45.
20,006 Springfield rifles, caliber .45.
101 Springfield officers' rifles, caliber .45.
3,000 Colt's revolvers, caliber .45.
280 Smith & Wesson revolvers, caliber .43.
200 staff and foot officers' swords.

Class VII.

5,020 curry combs.
2,021 saddle blankets.
11,397 meat cans.
13,650 tin cups.
7,124 sets knives, forks, and spoons.
47,246 appendages for small arms.

Class VIII.

53,129 cartridge bags, filled.
1,556,130 carbine ball cartridges, caliber .45.
1,502,179 rifle ball cartridges, caliber .50.
1,247,287 rifle ball cartridges, caliber .45.
310 rifle blank cartridges, caliber .45.
50,000 rifle blank cartridges, caliber .58.
1,074,070 revolver ball cartridges, caliber .45.
219,600 revolver blank cartridges, caliber .45.
1,697,750 lead balls, caliber .45.
91,000 pounds hexagonal powder.
2,400 pounds cannon powder.
2,000 pounds mortar powder.
52,512 pounds rifle powder.
3,300 electric cannon primers.
47,300 friction primers.
1,270,250 cartridge primers.
183 fuses, experimental.

Class IX.

16 blocks, various.
14 chocks, various.
1 hand cart.
2 rollers, long.
25 shifting planks.
1 sling wagon, Laidley's.
5 platforms for mortars.
5 platforms for siege carriages.

Class X.

1,425 sabots, various.
600 tin straps, various.
105,212 spare parts for small arms.
132,394 parts of infantry equipments.
3,440 parts of cavalry accouterments.
101,646 parts of horse equipments.
535 parts of artillery carriages, various.
53,768 cartridge bags, empty, various.
30,500 cartridge shells, caliber .45.

Miscellaneous.

945 arm chests.
2,845 boxes, packing, wood.
344 boxes, packing, tin.
4,447 bolts and nuts, various.
38,993 pounds barrel molds.
962 tin cans.
1 400-ton testing machine.
1 metal testing machine.
1 cartridge breaking machine.
1 cartridge loading machine.
2 cartridge stamping machines.
1 cartridge weighing machine.
4 primer drilling machines.
3 primer sawing machines.
1 cartridge gauging machine.
1 horizontal boring machine.
1 power planer.
1 pressure dynamometer.
2 lathes.
1 star gauge, ring and points.
3 ring gauges.
238 boxes leather blacking.
7,002 pounds harness oil.
41 gallons lacquer.
150 cast-iron heating stoves for Quartermaster's Department.
10 tool-chests, various.
2,342 pounds black wax.
20,404 pounds white lead.
5,064 pounds paint.
2,795 sides leather.
42,003 pounds leather.

19,982 pounds rope, twine, and thread.
814,928 pounds iron beams.
80,965 pounds sheet copper.
3,493 tons coal.
201 sets reloading tools.
10,888 tools and utensils.

APPENDIX B.

Statement of ordnance, ordnance stores, &c., issued to the military establishment (except the militia) during the fiscal year ended June 30, 1879.

CLASS I.

5 Gatling guns, caliber .45, 10 barrels, long.
3 Gatling guns, caliber .45, 10 barrels, short.
4 Gatling guns, caliber .45, 5 barrels, short.
1 Gatling gun, caliber .50.
1 Gatling gun, caliber 1 inch.
2 Hotchkiss revolving guns, caliber 1.5 inches.
3 Hotchkiss revolving guns, caliber 1.65 inches.
6 3-inch rifled guns.
9 4½-inch rifled guns.
1 6-pounder bronze gun.
5 12-pounder bronze guns.
5 12-pounder mountain howitzers.
20 8-inch rifled guns.
2 8-inch siege howitzers.
2 24-pounder Coehorn mortars.
6 8-inch siege mortars.
6 10-inch siege mortars.
1 13-inch sea-coast mortar.

CLASS II.

3 beds and frames for short-barrel Gatling gun.
2 frames for short-barrel Gatling gun.
2 tripods for short-barrel Gatling gun.
4 Gatling gun carts.
2 Gatling battery carts.
5 carriages and limbers for long-barrel Gatling gun, caliber .45.
1 carriage and limber for Gatling gun, caliber .50.
1 carriage and limber for Gatling gun, caliber 1 inch.
2 1.5-inch Hotchkiss gun carriages and limbers, steel.
3 1.65-inch Hotchkiss carriages for mountain gun.
12 3-inch carriages and limbers.
12 3-inch caissons and limbers.
11 4½-inch siege carriages and limbers.
1 6-pounder carriage and limber.
4 12-pounder carriages and limbers.
6 12-pounder caissons and limbers.
2 12-pounder field-howitzer carriages and limbers.
3 12-pounder mountain-howitzer carriages.
6 12-pounder prairie carriages and limbers.
1 12-pounder prairie carriage limber.
2 30-pounder Parrott carriages and limbers.
20 8-inch rifle carriages.
2 8-inch siege howitzer carriages and limbers.

3 24-pounder mortar beds.
6 8-inch siege mortar beds.
3 10-inch siege mortar beds.
1 13-inch sea-coast mortar bed.
2 mortar wagons and limbers.
10 cavalry forges, Laidley's.
1 portable forge.
2 traveling forges.
4 ammunition chests for Gatling tripod.
3 ammunition chests for mountain howitzer.

Class III.

2 accessories, feed cases, loading machines, &c., for 1½-inch Hotchkiss gun.
11 baskets for mortar implements.
1 iron forge bucket.
33 iron sponge buckets.
4 wooden sponge buckets.
24 iron tar buckets.
20 gutta-percha water buckets.
19 papier-maché water buckets.
16 leather water buckets.
3 drag-ropes.
4 elevating bars.
20 friction clamp bars, 8-inch carriage, long.
20 friction clamp bars, 8-inch carriage, short.
6 fuse blocks.
14 fuse cutters.
1 fuse extractor.
18 fuse mallets.
2 fuse plug reamers.
5 fuse plug wrenches.
1 fuse rasp.
14 fuse saws.
12 fuse setters.
8 fuse wrenches.
3 gunner's calipers.
46 gunner's gimlets, field.
14 gunner's gimlets, siege.
1 gunner's gimlet, 15-inch gun.
52 gunner's haversacks.
4 gunner's levels.
1 gunner's perpendicular.
12 gunner's pincers.
12 gunner's pouches.
4 gunner's quadrants, brass.
9 gunner's quadrants, wood.
11 pairs gunner's sleeves.
145 handspikes.
24 sets cavalry forge harness for two horses.
12 sets artillery harness for two lead horses.
19 sets artillery harness for two wheel horses.
56 harness-bags.
1 ladle and staff for 4½-inch gun.
2 common lanterns.

12 dark lanterns.
19 globe lanterns.
100 lanyards for friction primers.
2 loading tongs.
40 manœuvering bars.
1 maul.
7 pack saddles.
7 pass boxes.
8 paulins 5 by 5 feet.
17 paulins 6 by 10 feet.
84 paulins 12 by 15 feet.
11 pendulum hausses, 3-inch gun.
4 pendulum hausses, 12-pounder gun.
4 pendulum hausse pouches.
3 pendulum hausse seats.
8 pinch bars.
13 plummets and cords.
1 pointing cord.
6 pointing stakes.
5 powder funnels.
8 powder measures.
58 priming wires, field gun.
25 priming wires, siege gun.
2 priming wires, 15-inch gun.
26 prolonges.
4 props for 4½-inch gun.
4 props for howitzer.
6 quoins.
10 rammers and staves, 4½-inch gun.
2 rammers and staves, 15-inch gun.
40 rear eccentric axle bars, 8-inch carriages.
11 scrapers for mortars.
5 breech sights for 4½-inch siege gun.
2 breech sights for 8-inch siege howitzer.
4 front sights for 12-pounder gun.
5 front sights for 3-inch rifled gun.
3 front sights for 4½ inch siege gun.
2 front sights for 8-inch siege howitzer.
2 trunnion sights.
11 pairs shell hooks.
5 spatulas.
31 sponge covers, 3-inch gun.
6 sponge covers, 4½-inch gun.
2 sponge covers, 6-pounder gun.
13 sponge covers, 12-pounder gun.
2 sponge covers, 12-pounder field howitzer.
15 sponge covers, 12-pounder mountain howitzer.
1 sponge cover, 10-inch gun.
2 sponges and rammers, 6-pounder gun.
15 sponges and rammers, 12-pounder gun.
2 sponges and rammers, 12-pounder field howitzer.
27 sponges and rammers, 12-pounder mountain howitzer
27 sponges and rammers, 3-inch gun.
4 sponges and rammers, 8-inch siege howitzer.
10 sponges and staves, 4½-inch gun.
2 sponges and staves, 15-inch gun.

1 sponge and staff, 13-inch sea-coast mortar.
6 securing stakes.
12 stakes for mortar wagon.
135 thumbstalls.
2 tompions, 6-pounder gun.
12 tompions, 3-inch gun.
5 tompions, 4½-inch gun.
4 tompions, 12-pounder gun.
2 tompions, 24-pounder gun.
2 tompions, 8-inch siege howitzer.
2 tompions, 200-pounder gun.
2 tompions, 10-inch mortars.
12 tow hooks.
49 tube pouches.
50 vent covers, field gun.
9 vent covers, siege gun.
49 vent pieces, field gun.
25 vent punches, field gun.
3 vent punches, siege gun.
1 vent punch, 15-inch gun.
1 wiper for mortar.
6 worms and staves, field gun.
2 worms and staves, siege gun.
468 feed cases for Gatling gun, caliber .45.
7 clamps for worm gear, for Gatling gun, caliber .45.
9 gun covers, for Gatling gun, caliber .45.
9 drifts, for Gatling gun, caliber .45.
12 shell drivers.
8 extractors for headless cartridge shells, for Gatling gun, caliber .45.
1 extractor hook, for Gatling gun, caliber .45.
2 handles for wiping rod, for Gatling gun, caliber .45.
2 trail handspikes, for Gatling gun, caliber .45.
4 oscillators, for Gatling gun, caliber .45.
13 wiping rods, for Gatling gun, caliber .45.
12 lock screw drivers, for Gatling gun, caliber .45.
11 small screw drivers, for Gatling gun, caliber .45.
12 T screw drivers, for Gatling gun, caliber .45.
7 adjusting screw wrenches, for Gatling gun, caliber .45.
7 pin wrenches, for Gatling gun, caliber .45.
11 rear guide nut wrenches, for Gatling gun, caliber .45.
36 feed cases for Gatling gun, caliber .50.
5 gun covers, for Gatling gun, caliber .50.
36 feed cases, for Gatling gun, caliber 1 inch.
1 gun cover, for Gatling gun, caliber 1 inch.
1 front sight cover, for Gatling gun, caliber 1 inch.
1 butt gear extractor, for Gatling gun, caliber 1 inch.
3 extractor hooks, for Gatling gun, caliber 1 inch.
1 lock, for Gatling gun, caliber 1 inch.
3 butt gear pins, for Gatling gun, caliber 1 inch.
3 extracting pins, for Gatling gun, caliber 1 inch.
3 firing pins, for Gatling gun, caliber 1 inch.
1 extracting rod, for Gatling gun, caliber 1 inch.
1 wiping rod, for Gatling gun, caliber 1 inch.
3 lock springs, for Gatling gun, caliber 1 inch.
1 screw driver and fork wrench, for Gatling gun, caliber 1 inch.
1 eye-pin wrench, for Gatling gun, caliber 1 inch.

CLASSES IV AND V.

1,000 1.5-inch Hotchkiss shell.
1,143 1.65-inch Hotchkiss shell.
75 3-inch shot.
1,064 3-inch shell.
402 3-inch case.
348 3-inch canister.
128 12-pounder shot.
624 12-pounder shell.
86 12-pounder case.
472 12-pounder canister.
91 4½-inch shot.
228 4½-inch shell.
100 24-pounder shell.
350 30-pounder shot.
206 30-pounder shell.
200 100-pounder shell.
25 200-pounder (hollow) shot.
60 8-inch shot.
100 8-inch shell.
159 10-inch shell.

CLASS VI.

Muzzle-loading.

10 Springfield rifle muskets, caliber .58.
1,262 smooth-bore pistols, caliber 54.

Breech-loading.

201 Hotchkiss magazine carbines, caliber .45.
20 Sharps carbines, caliber .50.
2,177 Springfield carbines, caliber .45.
202 Hotchkiss magazine rifles, caliber .45.
12 Springfield rifles, caliber .50.
6,410 Springfield rifles caliber .45.
5 Springfield rifles, caliber .45, officer's model.
873 Colt revolvers, caliber .45.
6 Remington pistols, caliber .50.
12 Remington revolvers, caliber .44.
169 Schofield's Smith & Wesson revolvers, caliber .45.
6 Smith & Wesson revolvers, caliber .44.
22 artillery sabers.
482 cavalry sabers.
21 musicians' swords.
37 non-commissioned officers' swords.
6 staff and foot officers' swords.
25 riflemen's knives.
841 trowel bayonets.

CLASS VII.

41 artillery saber belts.
25 artillery saber belt plates.
1 brace yoke with carbine sling.

335 carbine cartridge boxes.
766 carbine cartridge pouches.
1,873 carbine slings.
1,253 carbine sling swivels.
40 pistol cartridge boxes.
921 pistol cartridge pouches.
2,997 pistol holsters.
2,264 saber belts.
2,245 saber belt plates.
253 saber knots.
86 brace yokes and stay straps.
2,885 steel bayonet scabbards.
791 trowel bayonet scabbards.
1,001 blanket bags.
11,413 canteens and straps.
1,969 carrying braces.
200 cartridge belts, caliber .50.
7,509 cartridge belts, caliber .45.
4,296 cartridge boxes, caliber .45.
138 cartridge boxes, No. 1.
279 cartridge boxes, No. 2.
77 cartridge loops.
6,251 clothing bags.
4,482 coat and blanket straps.
80 sliding frogs.
9,744 forks.
5,815 gun slings.
11,538 haversacks and straps.
9,751 knives.
9,619 meat cans.
447 scabbards for intrenching tools.
43 sheaths for knives.
276 shoulder braces.
9,179 spoons.
12 non-commissioned officers' sword belts and plates.
151 stay straps.
866 steady straps.
252 hoop straps.
10,817 tin cups.
364 valises.
165 valise straps.
113 non-commissioned officers' waist belts and plates.
3,647 privates' waist belts.
3,566 privates' waist belt plates.
5,000 brass muzzle covers.
7,003 headless shell extractors.
1,357 tumbler punches.
944 jointed ramrods, steel.
198 wiping rods.
3 ball screws.
8,475 screw drivers.
3 clamp screw drivers.
290 combination screw drivers and hoof hooks.
341 spring vises.
848 brush wipers and thongs.
12 wipers.

4, 011 curb bridles.
2, 365 watering bridles.
482 hair cinchas.
369 cruppers.
5, 888 curry combs.
1, 845 girths.
4, 551 halters and straps.
7, 593 horse brushes.
435 horse covers, cotton duck.
5, 821 lariats.
1, 250 links.
6, 943 nosebags.
2, 356 picket pins.
2, 001 saddles.
4, 293 saddle bags.
486 saddle blankets, artillery.
5, 171 saddle blankets, cavalry.
141 saddle cloths.
156 forage sacks.
3, 644 side lines.
877 carbine sockets.
4, 488 spurs.
4, 698 spur straps.
3, 432 stirrups.
27 stirrups with guidon sockets.
3, 652 stirrup straps.
2, 438 surcingles.

CLASS VIII.

SMALL-ARM AMMUNITION.

Paper cartridges.

10, 000 rifle ball cartridges, caliber .58.

Metallic cartridges.

300 Gatling ball cartridges, caliber 1 inch.
29, 845 rifle ball cartridges, caliber .50.
6, 000 rifle blank cartridges, caliber .50.
300 pistol ball cartridges, caliber .50.
1, 157, 470 carbine ball cartridges, caliber .45.
2, 305, 865 rifle ball cartridges, caliber .45.
243, 700 rifle blank cartridges, caliber .45.
457, 516 revolver ball cartridges, caliber .45.
46, 000 revolver blank cartridges, caliber .45.
9, 000 multiball cartridges, caliber .45.
6, 500 revolver ball cartridges, caliber .44.
1, 736, 210 small-arm cartridge primers.

Ammuniton for field guns.

10, 989 blank cartridges, 12-pounder mountain howitzer.
16, 721 blank cartridges, 12-pounder gun.
6, 396 blank cartridges, 6-pounder gun.

15,511 blank cartridges, 3-inch gun.
300 blank cartridges, 1-pound charge.
3,920 blank cartridges, ½-pound charge.
1,000 electric primers.
84,463 friction primers.
1,016 fuses.
6,000 pounds cannon powder.
10,000 pounds hexagonal powder.
4,100 pounds mammoth powder.
100 pounds mealed powder.
21,284¾ pounds mortar powder.
17,551 pounds musket and rifle powder.
12 portfires.
70 quick matches.

Class IX.

1 stadia bag.
30 fencing bayonets.
6 blocks.
1 half block.
2 sets pulley blocks.
4 quarter blocks.
2 hand carts.
3 sling carts.
2 sling chains.
6 gun chocks.
6 roller chocks.
16 wheel chocks.
2 garrison gins.
5 hydraulic jacks.
3 lifting jacks.
30 fencing muskets.
1 shifting plank.
1 platform, 4½ inch gun.
5 platforms, siege mortar.
2 long rollers.
2 short rollers.
2 trace ropes.
1 sheave for siege gin.
13 brass stadia.
1 silver stadium.
4 plane tables.
450 intrenching tools.
3 store trucks.

Class X—II.

1 axle.
1 splinter bar.
2 bolsters.
1 limber fork.
3 gibbs.
2 lever catch hooks.
6 keys and chains.
6 keys and pins.
6 pintles and chains.

12 linch pins and washers.
6 stay pins.
2 trunnion plates.
18 poles.
9 pole props.
3 middle rails.
8 side rails.
2 pointing rings.
6 elevating screws.
10 sockets for eccentric chassis.
3 thills.
36 linch washers.
16 shoulder washers.
28 wheels.
1 pole yoke.
6 keys and chains, Gatling carriage, caliber .50.
5 pintle keys and chains, Gatling carriage, caliber .50.
12 keys and pins, Gatling carriage, caliber .50.
6 linch pins, Gatling carriage, caliber .50.
6 stay pins, Gatling carriage, caliber .50.
6 washers, Gatling carriage, caliber .50.
14 bucket rings or carriers, Gatling carts, caliber .45.
6 extension chains.
6 plate hooks.
6 tug hooks.
8 shaft props.
2 outside shafts.
4 hasp and plate staples.
6 plate staples.
6 saddle shaft tug straps.
6 single trees.
16 saddle shaft tugs.
1 washer for end of main shaft.

Class X—III.

12 belly bands.
2 artillery bits.
53 artillery bridles.
1 breeching for mountain howitzer harness.
10 bridles for mountain howitzer harness.
312 brass plated buckles.
1,071 iron roller buckles.
25 collars.
12 cruppers.
9 girths.
1 lashing girth.
12 leg guards.
134 halters.
9 rammer heads, 3-inch.
4 rammer heads, 12-pounder.
1 rammer head, mountain howitzer.
15 sponge heads, 3-inch.
4 sponge heads, 12-pounder.
1 sponge head, mountain howitzer.
36 cold shut links.

4 loops for breast straps.
17 pole pads.
2 lashing ropes.
69 rosettes for artillery bridles.
158 woolen sponges, 3-inch.
34 woolen sponges, 4½-inch.
24 woolen sponges, 6-pounder.
81 woolen sponges 12-pounder.
26 woolen sponges, mountain howitzer.
1 rammer staff, 3-inch.
4 staves, 12-pounder.
5 breast straps.
116 halter straps.
8 hame straps.
12 loin straps.
81 pole straps.
4 tompion straps.
12 trussing straps.
1 pair traces for Gatling cart harness.
16 traces for patent splinter bar.
67 lead traces.
20 wheel traces.
12 valises.
164 whips.

CLASS X—IV AND V.

200 10-inch sabots.
200 10-inch tin straps.

CLASS X—VI.

Parts Springfield rifles, caliber .50, model 1866.

20 ejector springs.
10 ejector spring caps.
20 ejector spring cap screws.
10 hinge screw nuts.
10 thumb pieces.
20 thumb piece screws.

Parts Springfield rifle, caliber .50, model 1868.

50 stocks, complete.

Parts Springfield "Cadet" rifle, caliber .45.

6 butt plates.
5 ramrods.
40 stocks, wood part.

Parts Springfield rifle, caliber .45.

915 lower bands.
1,298 upper bands.
326 band springs.

20 band swivels.
15 band swivel pins.
40 band swivel screws.
14 barrels.
2 barrels and receivers.
710 bayonets.
359 bayonet clasps.
408 bayonet clasp screws.
310 bayonet clasp stop screws.
52 breech blocks.
124 breech block caps.
2,569 breech block cap screws.
80 breech screws.
553 bridles.
911 bridle screws.
43 butt plates.
231 butt plate screws.
110 cam latches.
2,034 cam latch springs.
3,588 ejector springs.
1,817 ejector spring spindles.
130 ejector studs.
556 extractors.
2,712 firing pins.
2,595 firing pin screws.
251 firing pin springs.
139 front sights.
104 guard bows.
348 guard bow nuts.
550 guard bow swivels.
1,200 guard bow swivel screws.
61 guard plates.
415 guard screws.
279 hammers.
295 hinge pins.
50 hinge pin studs.
6 locks.
81 lock plates.
1,372 main springs.
1,206 main spring swivels.
281 main spring swivel rivets.
550 ramrods.
130 ramrod stops.
393 rear sights (buckhorn).
112 rear sights, Bull's.
1,097 rear sights.
269 rear sight bases.
1,072 rear sight base screws.
359 rear sight base springs.
385 rear sight leaves.
691 rear sight joint pins.
479 rear sight slides.
484 rear sight slide springs.
669 rear sight slide spring rivets.
1,861 sears.
836 sear screws.

1,335 sear springs.
573 sear spring screws.
947 side screws.
548 side screw washers.
210 stocks, complete.
792 stocks, wood part
423 tang screws.
108 thumb pieces.
55 tips for stock.
96 tip screws.
128 triggers.
191 trigger screws.
2,068 tumblers.
1,888 tumbler screws.
10 pistol gripes for officers' rifles, caliber .45.

Parts Springfield carbine, caliber, .45.

135 bands.
160 stacking bands.
2 band springs.
2 barrels.
2 bridles.
7 bridle screws.
159 breech block cap screws.
16 breech screws.
70 butt plates.
30 butt plate covers and friction springs.
176 butt plate screws.
30 butt plate springs.
30 butt plate spring screws.
2 cam latches.
185 cam latch springs.
485 ejector springs.
215 ejector spring spindles.
6 ejector studs.
114 extractors.
212 firing pins.
213 firing pin screws.
125 firing pin springs.
846 front sights.
575 front sight pins.
200 front sight rivets.
25 front sight studs.
36 guard bows.
1 guard plate.
34 guard screws.
4 hammers.
42 hinge pins.
140 main springs.
240 ramrods.
14 sears.
7 sear screws.
152 sear springs.
5 sear spring screws.
73 side screws.

745 rear sights, complete.
1,123 rear sight bases.
150 rear sight base screws.
44 rear sight base springs.
161 rear sight leaves.
42 rear sight joint pins.
331 rear sight slides.
309 rear sight slide springs.
345 rear sight slide spring rivets.
1,335 stocks, complete.
360 stocks, wood part.
1,111 swivel bars.
1,256 swivel bar rings.
10 stacking swivels.
40 tang screws.
3 thumb pieces.
36 tumblers.
197 tumbler screws.
5 triggers.
10 trigger screws.

Parts Sharps carbine, caliber .50.

30 bands.
30 band springs.
10 barrel studs.
10 bridles.
20 bridle screws.
5 butt plates.
30 butt plate screws.
25 butt stocks.
10 extractors.
20 firing bolts.
30 firing bolt screws.
3 guard plates.
30 guard plate screws, front.
5 guard plate screws, rear.
5 hammers.
5 levers.
10 lever catches.
20 lever catch screws.
30 lever catch springs.
30 lever catch spring pins.
30 lever catch spring screws.
5 lever keys.
30 lever key stop springs.
40 lever key stop spring screws.
30 lever springs.
40 lever spring screws.
5 lock plates.
10 main springs.
30 main spring screws.
10 nose caps.
20 nose cap screws.
5 patch box lids.
15 primer covers.

30 primer cover pins.
15 primer shut-off screws.
22 primer slides.
20 primer spring screws.
10 rear sight bases.
40 rear sight elevator screws.
10 rear sight leaves.
30 rear sight joint pins.
20 rear sight slides.
20 rear sight springs.
40 rear sight spring screws.
15 sears.
30 sear screws.
20 side screws, front.
20 side screws, rear.
15 slide screws.
30 swivel bars.
60 swivel bar rings.
60 swivel bar screws.
30 swivel bases.
60 swivel screws.
25 tip stocks.
10 toggles.
20 toggle screws.
10 triggers.
20 trigger screws.
10 tumblers.
15 tumbler stirrups.
30 tumbler stirrup screws.

Parts of Hotchkiss magazine arms, caliber .45.

100 cartridge stop pins.
100 cut offs.
100 extractors.
100 firing pin screws.
40 magazine springs.
40 main springs.
100 trigger pins.
100 trigger spring screws.

Parts of Colts revolvers, caliber .45.

21 back straps.
198 back strap screws.
145 bolts.
135 bolt screws.
351 center pins.
226 center pin bushings.
405 center pin catch screws.
84 center pin screws.
25 cylinders.
255 ejector heads.
144 ejector rods.
3 ejector rod heads.
277 ejector springs.
153 ejector tubes.

201 ejector tube screws.
91 firing pins.
106 firing pin rivets.
10 frames.
50 front sights.
78 gates.
213 gate catches.
243 gate catch screws.
10 gate latch springs.
228 gate springs.
36 guards.
238 guard screws, long.
248 guard screws, short.
76 hammers.
128 hammer cams.
128 hammer rolls.
128 hammer roll rivets.
151 hammer screws.
128 hands.
173 hand springs.
116 main springs.
163 main spring screws.
50 recoil plates.
38 sear springs.
213 sear and stop bolt screws.
150 sear and stop bolt springs.
119 stocks.
25 stop bolt screws.
36 triggers.
148 trigger screws.

Parts of Schofield's Smith and Wesson revolver, caliber .45.

15 barrel catch spring.
3 cylinder catch cams.
5 cylinder catch cam screws.
18 cylinder catch screws.
18 extractors.
18 extractor springs.
18 extractor stems.
18 hand springs.
28 main springs.
18 pawl springs.
5 stop bolts.
13 stop springs.
18 strain screws.
25 triggers.
25 trigger springs.
2 musician's sword scabbards.
1 tip for musician's sword scabbard.
6 officer's nickel-plated sword scabbards.
6 trowel bayonet plugs.

CLASS X—VII.

472 saber belt attachment.
400 linen bags for saddle bags.

12 curb bits.
1,292 halter bolts.
891 assorted buckles.
14,268 brass bar buckles.
60 brass-plated buckles.
1,543 brass wire buckles.
3,036 iron bar buckles.
3,832 iron roller buckles.
2,417 canteen corks and chains.
409 halter chains.
105 curb chains and safes.
2,091 canteen covers.
1,500 brass D's for cartridge belts.
2,386 side line fasteners.
60 brass tips or ferrules for trowel bayonet scabbard.
90 bridle headstalls.
620 halter headstalls.
140 brass saber snap hooks.
700 stirrup hoods.
40 gunsling hooks.
512 sweat leathers.
140 curb strap loops.
36 iron stirrup loops.
2,916 ovals.
100 mouth pieces for curb bits.
171½ gross escutcheon screw pins.
200 escutcheon plates.
10 curb bridle reins.
20 watering bridle reins.
4,836 brass rings.
1,764 D rings.
3,141 halter rings.
1,361 iron rings.
95 leather seats for canvas saddle bags.
532 shields.
200 slides for saber belt attachment.
36 snaps for links.
367 snaps for side lines.
38$\frac{7}{36}$ gross spring snaps.
1,375 halter squares.
2,796 brass foot staples.
5,796 brass staples for rings.
1,000 coat strap stops.
1,002 blanket bag straps.
6,815 canteen straps.
45 cartridge belt straps with brass tips.
120 cincha straps.
3,995 clothing bag straps.
3,025 coat straps.
4 crupper and back straps.
90 curb straps.
4,026 halter straps.
335 halter hitching straps.
3,345 haversack straps.
3 hook straps.
51 girth straps.

532 saddle bag studs.
1 cavalry saddle tree.
2,644 yards linen webbing, 4 inches wide.
168 yards linen webbing, 4½ inches wide.
1,687 yards linen webbing, 7½ inches wide.
600 yards woolen webbing, 4 inches wide.

Class X—VIII.

738,000 bullets, caliber .45.
4,300 cartridge bags for 6-pounder gun.
7,450 cartridge bags for 12-pounder gun.
1,299 cartridge bags for 12-pounder mountain howitzer.
1,000 cartridge bags for 24-pounder howitzer.
2,500 cartridge bags for 30-pounder gun.
500 cartridge bags for 100-pounder gun.
50 cartridge bags for 200-pounder gun.
500 cartridge bags, assorted.
2,200 cartridge bags, ½-pound charge.
2,000 cartridge bags, 1½-pounds charge.
1,000 cartridge bags, 2-pounds charge.
6,550 cartridge bags for 3-inch gun.
1,115 cartridge bags for 4½-inch gun.
80 cartridge bags for 8-inch gun.
745 cartridge bags for 10-inch gun.

PART SECOND.

50 yards burlaps.
30 feet carding cloth.
2,102 pieces card clothing.
55 yards cotton cloth.
79½ pounds sash cord.
99 pounds waste cotton.
1 pound hemp, packing.
60 pounds marline.
1,595 pounds assorted rope.
18 pounds assorted thread.
90¾ pounds patent linen thread.
334 2/16 pounds saddler's thread.
599⅜ pounds shoe thread.
10 pounds tow.
320½ pounds twine.
1½ pounds woolen yarn.
6 spring bolts.
19 pounds burrs.
96 butts.
369 toe calks.
60 pressure discs.
36 hinges.
859 pounds bar iron.
544 pounds cast iron.
100 pounds hoop iron.
141 pounds plate iron.
38½ pounds copper nails.
1,055 pounds horseshoe nails.

750 pounds iron nails.
7,872 saddle nails.
18 pounds trunk nails.
298⅛ pounds brass rivets and burrs.
842¾ pounds copper rivets and burrs.
164 pounds iron rivets and burrs.
232 gross brass screws.
45 gross iron screws.
1 pound iron screws.
10,558 horseshoes
47¼ pounds solder.
1 pound spelter.
161 pounds bar steel.
76¾ pounds copper tacks.
664 papers iron tacks.
325⅛ pounds iron tacks.
50 sheets tin.
7¼ pounds copper wire.
33 pounds iron wire.
16 sheets zinc.
60½ feet alum tanned leather.
6 sides alum tanned leather.
65 feet belting leather.
1,227½ sides bridle leather.
50 feet buff leather.
7 sides collar leather.
27,704½ pounds harness leather.
150 leather pieces.
300 leather straps.
11½ pounds calfskins.
47 chamois skins.
3,424 feet boards.
845 feet plank.
418 feet scantling.
2,331 feet timber.
4 boxes elastic bands.
12 assorted books.
274 instruction books.
1 box crayons.
1,600 envelopes.
6 ink erasers.
4 boxes paper fasteners.
2 pieces India rubber.
8 bottles black ink.
4 bottles red ink.
5 bottles mucilage.
20 sheets blotting paper.
55 quires cap paper.
480 sheets drawing paper.
10 quires envelope paper.
1 quire folio paper.
140 quires letter paper.
2 reams note paper.
48 quires wrapping paper.
74 lead pencils.
1 gross metallic pens.

6 penholders.
2 bottles pounce.
500 paper tags.
11 pounds muriatic acid.
45 pounds sulphuric acid.
63 gallons alcohol.
100 pounds gum arabic.
161$\frac{11}{16}$ pounds beeswax.
306$\frac{5}{8}$ pounds blackwax.
487 quarts leather blacking.
10 pounds borax.
76 bath bricks.
4 ounces bristles.
4 pounds camphor.
21 pounds candles.
5 pounds chalk.
200 pounds pulverized charcoal.
30 quires crocus cloth.
1,209$\frac{1}{2}$ quires emery cloth.
6,563 pounds coal.
3 pounds copperas.
24$\frac{1}{4}$ gallons Japan drier.
11$\frac{1}{2}$ pounds emery.
40 pounds glue.
40 cans axle grease.
489$\frac{1}{2}$ pounds wheel grease.
278$\frac{1}{2}$ gallons lacker.
2 pounds lacker.
9 pounds lampblack.
500 pounds red lead.
855 pounds white lead.
17 pounds logwood.
8 boxes cleaning material.
16 pounds polishing material.
73$\frac{1}{2}$ pounds scouring material.
20$\frac{1}{2}$ quarts browning mixture.
400 pounds refined niter.
10 pounds nutgalls.
15 gallons astral oil.
1 gallon coal oil.
56$\frac{1}{2}$ quarts cosmoline oil.
6 gallons harness oil.
4,264 pounds harness oil.
80 gallons kerosene oil.
8 gallons lard oil.
659$\frac{5}{24}$ gallons linseed oil.
34 gallons mystic oil.
2 gallons naiad oil.
120 gallons neatsfoot oil.
677$\frac{1}{2}$ gallons sperm oil.
2 gallons sweet oil.
1,006 pounds black paint.
84 pounds lead-color paint.
1,810 pounds metallic paint.
2,590 pounds olive paint.
840 pounds red paint.

$21\frac{12}{24}$ quires emery paper.
750 pounds laboratory paper.
48 pounds log paper.
500 pounds packing paper.
240 pounds petroleum paper.
$160\frac{23}{24}$ quires sand paper.
12 pounds wrapping paper.
6 pounds leather polish.
224 pounds chlorate of potash.
104 pounds putty.
3 pounds rosin.
75 pounds gum shellac.
2,255 pounds soap.
1 quart soldering solution.
$91\frac{1}{8}$ pounds sponge.
20 pounds pumice stone.
$498\frac{1}{2}$ pounds rotten stone.
142 pounds nitrate of strontia.
300 pounds flowers of sulphur.
200 shipping tags.
$128\frac{1}{2}$ gallons coal tar.
5 pounds gum tragacanth.
368 papers tripoli.
2 pounds tripoli.
$556\frac{1}{2}$ gallons turpentine.
77 gallons varnish.
10 pounds vermilion.
28 pounds sealing wax.
10 gallons whiskey.
$93\frac{1}{2}$ pounds whiting.

Tools, &c.

2 carpenter's adzes.
3 anvils.
20 leather aprons.
8 augers and handles.
714 assorted awls.
4 peg awls and handles.
47 saddler's awls.
2 seat awls and handles.
99 stitching awls.
2 stub awls and handles.
7 assorted axes.
1 broad ax.
24 felling axes.
1 hand ax.
2 canvas nail bags.
35 bags for tacks, wax, &c.
3 tool bags for saddler's and smith's tools.
1,743 metallic powder barrels.
542 wooden powder barrels.
2 baskets.
1 bell with hangings, complete.
1 table bell.
2 bevels.

98 assorted bits.
61 bits for brace.
4 saw blades.
6 hack-saw blades.
1 web-saw blade.
1 anvil block.
19 lead punching blocks.
1 copper boiler.
7 bottles.
6 wooden bowls.
5 boxes for forge and battery wagon stores.
1 box for Gatling gun.
3 shoeing boxes.
12 assorted iron braces.
248 corn brooms.
297 assorted brushes.
4 counter brushes.
3 dusting brushes.
10 marking brushes.
235 paint brushes.
9 sash brushes.
20 wire scratch brushes.
3 varnish brushes.
6 whitewash brushes.
12 water buckets.
46 galvanized iron water buckets.
2 buttresses.
6 calipers.
3 oil cans.
67 tin cans.
1,512 powder canisters.
2 hand creasing carriages.
39 pricking carriages.
6 chamois-skin sword cases.
3 channelers.
537 arm chests.
2 forage chests.
3 black walnut chests.
11 tool chests.
31 assorted chisels.
13 firmer chisels.
1 framing chisel.
22 saddler's clamps.
1 steel clamp.
10 vise clamps.
1 clock.
3 collets.
52 compasses.
9 finger cots.
2 countersinks.
57 creasers.
1 desk.
6 reloading dies.
1 resizing die.
1 divider.
2 turning dogs.
1 drift.

20 assorted drills.
17 oil droppers.
1 feather duster.
1 steam engine.
2 nail extractors.
15 primer extractors.
2,168 assorted files.
1 fleam.
4 floats.
1 copper funnel.
4 furnaces.
4 carpenter's gauges.
10 draw gauges.
1 mortise gauge.
1 saddler's gauge.
1 wire gauge.
16 gimlets.
15 carpenter's gouges.
1 firmer gouge.
2 saddler's gouges.
2 grindstones with arbors and cranks.
1 portable grindstone.
126 assorted hammers.
1 claw hammer.
1 copper hammer.
3 riveting hammers.
3 saddler's hammers.
1 shoeing hammer.
1 adze handle.
258 awl handles.
3 patent awl handles.
12 ax handles.
85 file handles.
2 mattock handles.
8 pickax handles.
6 tool handles.
4 hardies.
9 hatchets.
1 bayonet clasp holder.
5 reaping hooks.
9 saddler's horses.
17 stitching horses.
4 clenching irons.
18 riveting irons.
3 rounding irons.
7 soldering irons.
1 jack screw.
255 assorted knives.
2 drawing knives.
3 gauge knives.
4 half round knives.
5 head knives.
12 shoe knives.
6 shoeing knives.
12 splitting knives.
1 spirit lamp with cup.
1 spirit level.

28 chalk lines.
89 padlocks.
1 leather creasing machine.
1 sewing machine.
3 leather splitting machines.
43 mallets.
2 mattocks.
7 tape measures.
4,955 assorted needles.
6 collar needles.
1 paper harness needles.
50 saddler's needles.
55 papers saddler's needles.
58 nippers.
2 sewing palms.
1 iron pan.
4 pickaxes.
12 assorted pincers.
14 assorted planes.
1 foreplane.
1 jackplane.
1 moulding plane.
1 philister plane.
1 plow plane.
1 smoothing plane.
32 pliers.
660 wooden plugs.
2 pokers.
4 glue pots.
6 paint pots.
1 letter press.
1 saddler's tool-pouch.
5 pritchels.
38 assorted punches.
16 bullet punches.
68 hand punches.
2 reloading punches.
16 saddler's punches.
49 spring punches.
1 iron rack.
1 rake.
88 rasps
13 reamers.
2 chalk-line reels.
1 riffler.
4 wiping rods.
44 2-feet rules.
1 measuring rule.
1 iron safe.
25 assorted saws.
2 compass saws.
1 frame saw.
5 handsaws.
1 rip saw.
2 tenon saws.
1 counter scales.
1 letter scales.

1 platform scales.
13 scissors.
1 barrel scraper.
1 box scraper.
41 screwdrivers.
4 screwdrivers for brace
1 screw plate with dies and taps.
2 scribers.
18 scythes.
4 scythe snaths.
9 assorted sets.
17 burr or rivet sets.
4 saw sets.
50 shears.
1 bench shears.
1 tinner's shears.
7 sickles.
7 sieves.
18 assorted shovels.
10 long-handled shovels.
1 smith's shovel.
26 slickers.
6 magazine slippers.
1 safety socket.
7 spades.
5 spokeshaves.
17 squares.
1 seal stamp.
4 sets brass stencil cutters, letters, and figures.
1 set steel stencil cutters, letters, and figures, ½ inch.
1 set steel stencil cutters, letters, and figures, ¾ inch.
1 set loop sticks.
3 die stocks and dies.
1 drill stock.
37 oil stones.
39 sand stones.
6 scythe stones.
1 straight edge.
7 assorted taps.
82 thimbles.
30 ticklers.
59 tongs.
33 claw tools.
83 edge tools.
180 sets cartridge reloading tools.
71 sash tools.
1 pair trammels.
25 tubes for spring punch.
17 assorted vises.
7 hand vises.
12 buffing wheels.
6 emery wheels.
117 pricking wheels.
1 wheelbarrow.
1 monkey wrench.
50 screw wrenches.
1 wrench for vent piece.

APPENDIX C.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1879, *under sections* 1661 *and* 1667 *Revised Statutes United States, and regulations established in conformity therewith.*

States and Territories.	Number of Senators and Representatives.	Money-value.
Alabama	10	$4,797 85
Arkansas	6	2,878 71
California	6	2,878 71
Connecticut	6	2,878 71
Delaware	3	1,439 36
Florida	4	1,919 14
Georgia	11	5,277 64
Illinois	21	10,075 49
Indiana	15	7,196 78
Iowa	11	5,277 64
Kansas	5	2,398 93
Kentucky	12	5,757 42
Louisiana	8	3,838 28
Maine	7	3,358 50
Maryland	8	3,838 28
Massachusetts	13	6,237 21
Michigan	11	5,277 64
Minnesota	5	2,398 93
Mississippi	8	3,838 28
Missouri	15	7,196 78
Nebraska	3	1,439 36
Nevada	3	1,439 36
New Hampshire	5	2,398 93
New Jersey	9	4,318 06
New York	35	16,792 48
North Carolina	10	4,797 85
Ohio	22	10,555 27
Oregon	3	1,439 36
Pennsylvania	29	13,913 76
Rhode Island	4	1,919 14
South Carolina	7	3,358 50
Tennessee	12	5,757 42
Texas	8	3,838 28
Vermont	5	2,398 93
Virginia	11	5,277 64
West Virginia	5	2,398 93
Wisconsin	10	4,797 85
Arizona Territory *	3	1,439 36
Colorado Territory *	3	1,439 36
Dakota Territory *	3	1,439 36
Idaho Territory *	3	1,439 36
New Mexico Territory *	3	1,439 36
Montana Territory *	3	1,439 36
Utah Territory *	3	1,439 36
Washington Territory *	3	1,439 36
Wyoming Territory *	3	1,439 36
District of Columbia *	3	1,439 36
Total	396	189,995 00
Freights, &c		11,005 00
		200,000 00

* Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX D.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1878, *to June* 30, 1879, *under sections* 1661 *and* 1667 ***Revised Statutes United States.***

CLASS I.

6 6-pounder bronze guns.
4 light 12-pounder bronze guns.
4 3-inch wrought-iron rifled guns.
1 Gatling gun, caliber 1 inch.

CLASS II.

6 carriages and limbers for 6-pounder gun.
5 carriages and limbers for light 12-pounder guns.
4 carriages and limbers for 3-inch gun.
1 carriage and limber for Gatling gun, caliber 1 inch.
7 caissons and limbers for light 12-pounder gun.
4 caissons and limbers for 3-inch gun.

CLASS III.

2 sponge buckets, iron, for field guns.
1 tar bucket, iron, for field guns.
2 watering buckets.
30 feed cases for Gatling guns, caliber 1 inch.
19 gunners' haversacks.
8 gunners' gimlets.
14 handspikes, trail.
25 sets of artillery harness, 2 horses, wheel.
22 sets of artillery harness, 2 horses, lead.
76 lanyards for friction primers.
4 pendulum hausses.
4 pendulum hausse seats.
22 paulins, 12 by 15 feet.
12 prolonges.
17 priming wires.
10 sponges, woolen, 12-pounder gun.
5 sponges, woolen, 3-inch gun.
8 sponge heads, 3-inch gun.
8 sponges and rammers, 6-pounder gun.
8 sponges and rammers, 3-inch gun.
18 sponges and rammers, 12-pounder gun.
8 sponge covers, 6-pounder gun.
8 sponge covers, 3-inch gun.
10 sponge covers, 12-pounder gun.
84 thumbstalls.
4 tompions, for 3-inch gun.
4 tompions, for 12-pounder gun.
6 tow hooks.

19 tube pouches.
13 vent covers.
5 vent punches.
4 artillery whips.
1 worm and staff, for 6-pounder gun.
2 worms and staves, for 12-pounder gun.

CLASS V.

60 6-pounder shot, strapped.
20 3-inch shot, fully prepared.
60 12-pounder shot, strapped.
32 12-pounder shot, fixed.
16 12-pounder shells, fixed.
40 3-inch case shot, fully prepared.
32 12-pounder case shot, fixed.
90 3-inch canister, fully prepared.
25 6-pounder canister, filled and fixed.
44 12-pounder canister, filled and fixed.

CLASS VI.

Breech-loading.

241 Springfield rifles, caliber .50.
5,269 Springfield rifles, caliber .45.
1 Springfield rifle, officers' model, caliber .45.
319 Springfield carbines, caliber .45.
40 Spencer carbines, caliber .50.
380 Smith and Wesson revolvers, caliber .44.
612 Schofield Smith and Wesson revolvers, caliber .45.
1,030 Colt's revolvers, caliber .45.
14 officers' swords, with two scabbards.
245 light artillery sabers.
130 light cavalry sabers.
114 non-commissioned officers' swords.
12 bayonets for caliber .45 rifles.

CLASS VII.

200 sets infantry accouterments.
1 valise.
290 saber belts and plates.
60 saber knots.
100 brace yokes and stay straps.
110 non-commissioned officers' sword belts and plates.
200 haversacks and straps.
51 carbine slings and swivels.
200 carbine cartridge pouches.
550 pistol cartridge pouches.
750 pistol holsters.
3,392 steel bayonet scabbards.
200 leather bayonet scabbards.
530 cartridge boxes, caliber .50.
3,470 cartridge boxes, caliber .45.
3,337 gun slings.

3,760 waist belts and plates.
40 sets horse equipments.
23 curb bridles.
10 watering bridles.
390 cavalry saddles.
4 artillery drivers' saddles.
100 girths.
10 halters and straps.
10 pairs saddle-bags.
30 saddle blankets.
25 felt saddle cloths.
2 sweat leathers.

Class VIII.

458 blank cartridges for 3-inch gun.
700 blank cartridges for light 12-pounder gun.
5,000 elongated ball cartridges, paper, calibre .54.
10,000 elongated ball cartridges, paper, caliber .58.
1,139,000 rifle ball cartridges, caliber .50.
416,000 rifle ball cartridges, caliber .45.
500 multiball cartridges, caliber .45.
12,000 carbine ball cartridges, caliber .50.
12,300 carbine ball cartridges, caliber .45.
1,200 pistol ball cartridges, caliber .44.
7,400 pistol ball cartridges, caliber .45.
2,000 ball cartridges for Gatling gun, caliber 1 inch.
27,000 rifle blank cartridges, caliber .50.
64,000 rifle blank cartridges, caliber .45.
500 pounds cannon powder.
2,000 pounds mortar powder.
1,750 friction primers.
4,000 percussion caps.

Class X.

9 spare wheels.
31 pole pads.
4 pairs pole straps.
2 spare poles.

Spare parts for Springfield rifle, caliber .50.

1 stock.
153 firing pins.
111 firing pin springs.
3 cam latch springs.
5 breech screws.
9 upper band swivels.
50 buckhorn sights complete.

Spare parts for Springfield rifle, caliber .45.

11 stocks.
4 tips.
1 ramrod.

1 ramrod stop.
5 band springs.
2 side screw washers.
2 butt plates.
4 butt plate screws.
1 bridle.
14 band screws.
1 bayonet clasp screw.
3 breech block cap screws.
500 firing pins.
500 firing pin springs.
1 guard bow swivel.
1 guard bow swivel screw.
7 guard screws.
1 lock.
8 lower bands.
6 upper bands.
1 upper band swivel.
1 upper guard screw.
4 rear sights.
3 rear sight bases.
4 rear sight base springs.
20 rear sight joint screws.
14 rear sight base screws.
204 rear sight leaves.
24 rear sight leaf screws.
221 rear sight slides.
2 sear springs.
6 side screws.
123 tumblers.
37 tumbler screws.
4 tang screws.

MISCELLANEOUS.

1 felling ax.
1 pickax.
1 long-handled shovel.
1,000 Hoffman attachments.
1 primer ejecting machine.
1 powder charging machine.
1 resizing machine.
1 pressing and crimping machine.

APPENDIX E.

Statement of ordnance, ordnance stores, &c., distributed to colleges and universities from July 1, 1878, to June 30, 1879, under section 1225 Revised Statutes United States, as amended by act approved July 5, 1876.

CLASS I.

4 6-pounder bronze guns.
6 3-inch wrought iron guns.

CLASS II.

2 6-pounder gun carriages and limbers.
6 3-inch gun carriages and limbers.
2 caissons and limbers for 6-pounder guns.
4 caissons and limbers for 3-inch guns.

CLASS III.

10 gunners' haversacks.
10 handspikes.
20 lanyards for friction primers.
10 priming wires.
8 paulins, 12 by 15 feet.
1 3-inch pendulum hausse.
1 seat for pendulum hausse.
1 pouch for pendulum hausse.
4 sponges for 6-pounder gun.
4 sponge covers for 6-pounder gun.
16 sponge covers for 3-inch gun.
6 sponges and rammers, 6-pounder gun.
18 sponges and rammers, 3-inch gun.
20 thumbstalls.
6 tompions, 3-inch gun.
10 tube pouches.
10 vent covers.

CLASS VI.

667 Springfield "cadet" rifles, caliber .45.
28 non-commissioned officers' swords, steel scabbards.

CLASS VII.

8 non-commissioned officers' shoulder belts and plates.
30 saber belts and plates.
667 steel bayonet scabbards.
667 cartridge boxes, caliber .45.
667 waist belts and plates.

Class VIII.

1,150 blank cartridges for 6-pounder gun.
500 blank cartridges for 3-inch gun.
100 blank cartridges for 12-pounder gun.
1,000 rifle ball cartridges, caliber .50.
1,000 rifle ball cartridges, caliber .45.
5,500 carbine ball cartridges, caliber .50.
10,500 carbine ball cartridges, caliber .45.
7,500 rifle and carbine blank cartridges, caliber .50.
11,500 rifle and carbine blank cartridges, caliber .45.
5,550 friction primers.
100 pounds mortar powder.
10 time fuses for 8-inch mortar shells.

APPENDIX F.

Statement of ordnance stores, &c., distributed to the Territories and States bordering thereon, from July 1, 1878, *to June* 30, 1879, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878, *and the act of May* 16, 1878.

2,470 Springfield rifles, caliber .50.
470 leather bayonet scabbards.
470 cartridge boxes, caliber .58.
470 gun slings.
470 waist belts and plates.
123,500 rifle ball cartridges, caliber .50.

APPENDIX G.

Statement of ordnance and ordnance stores, &c., issued to the Executive Departments, under the provisions of the act of March 3, 1879.

Class VI.

8 Springfield rifles, caliber .50.
100 Springfield rifles, caliber .45.
12 Springfield carbines, caliber .45.
420 Colt's revolvers, caliber .45.

Class VII.

100 cartridge boxes.
220 pistol holsters.
320 waist belts and plates.

Class VIII.

400 rifle ball cartridges, caliber .50.
6,000 rifle ball cartridges, caliber .45.
17,600 revolver ball cartridges, caliber .45.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

OFFICE OF THE CONSTRUCTOR OF ORDNANCE,
New York, October 2, 1879.

SIR: I have the honor to inclose herewith reports on the construction of the following-named ordnance, to wit:

11-inch muzzle-loading rifle, converted from a 15-inch smooth bore Rodman gun, breech insertion of lining.

3-inch breech-loading rifle.

3. 17-inch muzzle-loading chambered rifle.

3. 16-inch muzzle-loading rifle, "rapid twist."

Also reports on gas checks for breech-loading rifles, and the alteration made in the traverse gear of the 12-inch rifle chassis.

The above comprise all the experimental guns which have been constructed under the supervision of this office up to date, and since the date of my last reports published with the report of the Chief of Ordnance for the year 1878.

I am largely indebted to the services of Capt. Charles S. Smith and Lieut. C. W. Whipple, of the Ordnance Department, in the compilation of these reports from the data on the files of this office.

Very respectfully, your obedient servant,

S. CRISPIN,
Bvt. Col. U. S. A., Lieut. Col. of Ordnance,
Constructor of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

APPENDIX H.

CONSTRUCTION OF THE 11-INCH MUZZLE-LOADING RIFLE, CONVERTED FROM A 15-INCH SMOOTH BORE RODMAN GUN.

(One plate.)

PRELIMINARY REMARKS.

The conversion of this gun was undertaken in consequence of the success which attended the conversion of 8-inch muzzle-loading rifle No. 1, B. I.; and the details of construction and fabrication incident to this latter gun were followed in the 11-inch, modified, however, to the extent demanded by the increased sizes of all the parts.

The only important feature which distinguishes the 11-inch from its smaller prototype (8-inch B. I.) consists in the introduction of a wrought-iron sleeve, which unites, by means of screw-threads on its inner and outer surfaces, the cast-iron breech-plug and the breech portion of the jacket. (See plate.)

It was found impracticable with existing facilities to make the breech portion of the jacket thick enough to sufficiently overlap the bottom of the tube and exterior of its breech cup; but by the introduction of the wrought-iron sleeve this important condition is practically secured.

DESCRIPTION OF GUN.

Plate I represents in section the principal details, which are as follows: the original 15-inch smooth-bore, bored out to receive the lining; a tube of coiled wrought iron (welded), closed at bottom by a wrought iron cup; a hollow wrought-iron jacket shrunk upon the rear of the tube and projecting in rear of it to the face of the breech; the cast-iron breech-plug and its wrought-iron sleeve; the muzzle-collar; the securing-pins and the gas-escape.

It was designed leaving the bore of the casing, for a length of 94.5 inches from the muzzle, at its original diameter, but the discovery of an eccentricity necessitated its being bored out to 15.219 inches; consequently for this length the tube is 2.1095 inches thick—its least thickness—while the thickness of the tube and jacket over the seat of the charge is 3.75 inches.

For the purpose of correcting muzzle-preponderance the axis of the trunnions was moved 0.5 inch toward the muzzle, by reducing eccentrically the diameter from 15 to 14 inches.

RIFLING.

The rifling of the gun consists of 19 lands and grooves:

Width of lands, 0.91215 inch.

Width of grooves, 0.908 inch.

Twist uniform, one turn in 60 feet.

The rifling stops at a point 20 inches from the bottom of the bore, and the diameter of the unrifled portion of the bore is equal to that of the rifled portion across lands.

VENTING.

The old vent was closed (the copper bushing having been removed) by a wrought-iron screw-plug, and a new vent was made at a distance of 9.5 inches from the bottom of the bore, and 2.5 inches to the left of the vertical plane through the axis of the bore.

FABRICATION.

The tube was manufactured and work of conversion performed at the West Point Foundery; the gun selected for the conversion was 15-inch Rodman smooth-bore No. 113, manufactured at the South Boston Foundery in 1865.

Up to this time no tube had been made which required the manipulation of iron larger than that used in jackets for 8-inch tubes; and the capacity of the plant had to be, consequently, considerably increased.

In addition to new mandrels, welding-pots, anvils, dies, &c., cranes were strengthened, furnaces enlarged, and new appliances, such as cross-heads and rods, screw and head, butt staves, &c., made for the press-furnace.

Important alterations were also made in the rifling and other machines.

The tube was made of "A" quality Ulster tube-iron; the jacket of "B" quality Ulster tube-iron; and the forging for breech end of jacket from "A" quality Ulster product.

The following results were obtained by mechanical tests of the iron used.

The specimens of wrought iron were taken from the bar and with the fiber.

Specimens.	Length between shoulders.	Area cross-section.	Tenacity per sq. inch.	Elastic limit.	Extension per inch at rupture.	Remarks.
Wrought iron.	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	
1. From 3" square bar ("A" quality).	3.0	0.25338	48,000.00	24,000.00	0.285	For middle section of tube
2. From 2".75 square bar ("A" quality).	3.0	0.25428	49,000.00	25,000.00	0.301	For three front and two rear sections of tube.
3. From 3".5 hexagonal bar ("B" quality).	3.0	0.2563	47,278.00	22,750.00	0.2511	For front section of jacket, mean of four specimens.
4. From 5"½ square bar ("B" quality.)	3.0	0.20109	49,728.00	25,000.00	0.226	For rear coiled section of jacket, mean of two specimens.
Cast iron.						
5. From breech-plug.		1.113	30,571.00			

The tube was made of six coiled sections.

The iron as received from rolling-mill was as follows:

For two rear sections, 6 bars, 2.75 inches square, 20 feet long.

For following (or middle) section, 3 bars, 3.00 inches square, 19 feet 8 inches long.

For three forward sections, 9 bars, 2.75 inches square, 21 feet 4 inches long.

These bars were welded together in sets of three for each section.

For the two rear sections the bars were coiled over a 9.5-inch mandrel, and subsequently welded in the following "pots":

For first heat: $\left\{\begin{array}{l}\text{Upper diameter, } 15\frac{3}{8} \text{ inches}\\ \text{Lower diameter, } 15\frac{1}{8} \text{ inches}\end{array}\right\} \times 48$ inches high.

For second heat: $\left\{\begin{array}{l}\text{Upper diameter, } 15\frac{7}{8} \text{ inches}\\ \text{Lower diameter, } 15\frac{5}{8} \text{ inches}\end{array}\right\} \times 44$ inches high.

For the middle section the bar was coiled over a 10-inch mandrel, and welded in the following "pots":

For first heat: $\left\{\begin{array}{l}\text{Upper diameter, } 16\frac{7}{8} \text{ inches}\\ \text{Lower diameter, } 16\frac{5}{8} \text{ inches}\end{array}\right\} \times 48$ inches high.

For second heat: $\left\{\begin{array}{l}\text{Upper diameter, } 17\frac{1}{4} \text{ inches}\\ \text{Lower diameter, } 17\frac{1}{8} \text{ inches}\end{array}\right\} \times 44$ inches high.

For three forward sections the bars were coiled over a 10-inch mandrel, and welded in the following "pots":

For first heat: $\left\{\begin{array}{l}\text{Upper diameter, } 15\frac{7}{8} \text{ inches}\\ \text{Lower diameter, } 15\frac{5}{8} \text{ inches}\end{array}\right\} \times 46$ inches high.

For second heat: $\left\{\begin{array}{l}\text{Upper diameter, } 16\frac{1}{4} \text{ inches}\\ \text{Lower diameter, } 16\frac{1}{8} \text{ inches}\end{array}\right\} \times 44$ inches high.

All of the sections were then rough-bored, faced, and prepared for tube-welding in the usual manner; the middle section being turned down for a length of about 8 inches on either end, in order to accommodate it to the smaller diameters of the two contiguous sections.

The jacket was made in three sections; the rear one from a forged iron, and the two forward ones made of coiled wrought iron, received from the rolling-mill, as follows:

For front section, 3 bars, 4″ × 3″.35, hexagonal cross-section, 19 feet 8 inches long.

For middle section, 3 bars, $5\frac{1}{8}$″ square, 15 feet 4 inches long.

Each of these sets were welded together to form a single bar, and the larger was planed to the usual hexagonal cross-section.

For the front section the bar was coiled over a $12\frac{1}{4}$-inch mandrel, and welded in the following "pots":

For first heat: $\left\{\begin{array}{l}\text{Upper diameter, } 19\frac{7}{8} \text{ inches}\\ \text{Lower diameter, } 19\frac{5}{8} \text{ inches}\end{array}\right\} \times 50$ inches high.

For second heat: $\left\{\begin{array}{l}\text{Upper diameter, } 20\frac{1}{4} \text{ inches}\\ \text{Lower diameter, } 20\frac{1}{8} \text{ inches}\end{array}\right\} \times 46$ inches high.

For the middle section the bar was coiled over a $9\frac{3}{4}$-inch mandrel, and welded in the following "pots":

For first heat: $\left\{\begin{array}{l}\text{Upper diameter, } 21\frac{1}{8} \text{ inches}\\ \text{Lower diameter, } 21 \text{ inches}\end{array}\right\} \times 50$ inches high.

For second heat: $\left\{\begin{array}{l}\text{Upper diameter, } 21\frac{3}{4} \text{ inches}\\ \text{Lower diameter, } 21\frac{5}{8} \text{ inches}\end{array}\right\} \times 46$ inches high.

The "cheese" used in each case was about $\frac{1}{4}$ inch smaller in diameter than the pot, and about 10 inches in thickness.

The rear, forged section was bored to 10.5 inches, and cut to a length of about 26 inches.

The middle section, which was about 36 inches long, was bored for a length of 12 inches to a diameter of 10.5 inches, and for the remainder of its length to a diameter of 13.5 inches; for one-half of its length it was turned down on the exterior to a diameter of about 20 inches. The front section, about 36 inches long, was bored to 13.5 inches diameter.

After welding, the jacket was so cut as to throw the joint between the rear and middle sections at a distance of 8 inches from the base of the tube.

The tube was then rough-bored to 11 inches, fitted with a breech cup, and turned down to receive the jacket.

The jacket was bored to an interior diameter of about .003 inch less than the corresponding diameter of the tube, rough-turned to its proper exterior dimensions, and the screw-thread cut in its breech end for the wrought-iron sleeve.

Both tube and jacket were then proved with a water pressure of 180 pounds to the square inch.

The jacket was then shrunk upon the tube, which was subsequently placed in the lathe and finished bored.

The casing had in the mean time been prepared as follows: A "piercer" had been run from the muzzle through the breech, and the hole thus made gradually enlarged to the diameter of the bore.

The gun was then reversed in the lathe, and bored out, for successive lengths, to the required diameters. After the screw-thread had been cut in the breech, and the recess and threads cut for the muzzle-collar, the trunnions were turned down. Careful measurements were then made with the star-gauge of the entire bore, for every inch of length along both horizontal and vertical diameters, and the results plotted on paper. This served as a guide to the workman, who turned down the tube in accordance with it. The wrought-iron sleeve was then screwed into the breech end of the jacket, and secured there by two small screw-pins. The tube was then gradually inserted and screwed into place, an operation which was repeated six times before perfect contact of all the shoulders was obtained. The cast-iron breech-plug was then also screwed into place and secured by a pin; the muzzle collar, vent bushing, and four securing pins inserted, and the gas channel bored through the casing and jacket.

Table No. I shows the relative diameters of the tube and jacket, and of the bore of the casing.

INSPECTION.

Careful inspections were made of every detail incident to the construction, and the gun, after completion, finally inspected, accepted as satisfactory, and shipped to Sandy Hook for powder-proof.

Principal dimensions.

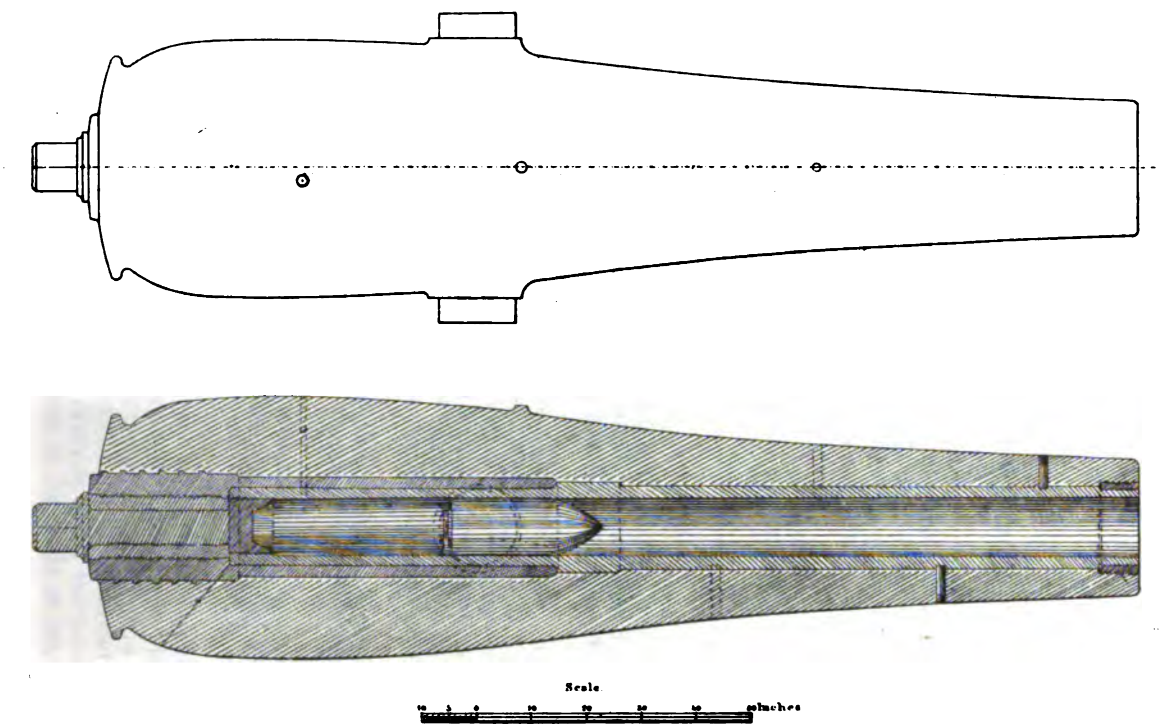
Subject of measurement.	Dimensions.
Total length of inner tube .... inches..	165.617
Length of jacket over tube .... do....	59.875
Interior diameter of jacket over tube .... do....	14.510
Diameter of tube under jacket .... do....	14.513
Shrinkage .... do....	.003
Length of jacket in rear of tube .... do....	25.5
Total length of complete tube .... do....	191.117
Total length of bore of casing .... do....	189.367
Depth of wrought-iron cup at bottom of tube .... do....	4.5
Thickness at bottom of wrought-iron cup .... do....	4.0
Diameter of interior of cup at top .... do....	8.85
Diameter of interior of cup at bottom .... do....	5.35
Diameter of finished tube from end of screw-thread to first shoulder .... do....	19,482
Diameter of bore of casing from end of screw-thread to first shoulder .... do....	19.491
Corresponding play .... do ...	.009
Diameter of finished tube from first shoulder to second shoulder .... do....	18.485
Diameter of bore of casing from first shoulder to second shoulder .... do....	18.490
Corresponding play .... do....	.005
Diameter of finished tube from second shoulder to third shoulder .... do....	15.989
Diameter of bore of casing from second shoulder to third shoulder .... do....	15.997
Corresponding play .... do....	.008
Diameter of finished tube from third shoulder to neck .... do...	15.215
Corresponding diameter of casing .... do....	15.219
Corresponding play .... do ...	.004
Length of chase (from neck to third shoulder) .... d	87.217
Length of first reinforce (from third to second shoulder) .... do....	11.125
Length of second reinforce (from second to first shoulder) .... do....	49.875

Principal dimensions—Continued.

Subject of measurement.	Dimensions.
Length of third reinforce (from first shoulder to screw-thread) .... inches..	14.60
Length of screw on jacket .... do....	19.75
Pitch of screw on jacket .... do....	3.7
Diameter of jacket across threads .... do....	20.3
Corresponding diameter of casing .... do....	20.31
Corresponding play .... do....	.01
Diameter of cast-iron breech-plug across threads .... do....	6.5
Length of cast-iron breech-plug .... do....	35.75
Diameter of wrought-iron sleeve for breech-plug across threads .... do....	12.3
Length of wrought-iron sleeve for breech-plug .... do....	25.2
Length of neck of tube .... do....	7.0
Length of muzzle collar .... do....	7.0
Length of recess in casing .... do....	7.4
Diameter of tube over neck .... do....	13.833
Interior diameter of muzzle collar .... do....	13.843
Corresponding play .... do....	.01
Diameter of muzzle collar across threads .... do....	16.75
Diameter of recess in casing .... do....	16.76
Play between collar and casing .... do....	.01
Thickness on collar .... do....	1.45
Pitch of thread on collar .... do....	0.75
Radius of curve at bottom of bore of jacket .... do....	0.62
Radius of curve at bottom of tube .... do....	0.75
Diameter of gas channel through casing .... do....	0.2
Distance of interior orifice below axis of bore .... do....	7.0
Distance of exterior orifice from tangent to base of gun .... do....	12.0
Length of bore .... do....	161.5
Length of rifled portion of bore .... do....	141.5
Diameter of bore across lands .... do....	11.008
Number of grooves and lands .... do....	19
Width of grooves .... do....	0.908
Width of lands .... do....	0.912
Depth of grooves .... do....	0.09
Pitch of rifling, one turn in .... feet...	59.886
Diameter of vent .... inches..	0.2
Diameter of vent bushing .... do....	1.0
Axis of vent from bottom of bore .... do....	9.5
Axis of vent from vertical plane through axis of bore (to the left) .... do....	2.5
Diameter of trunnions .... do....	14.0
Diameter of securing pins .... do....	1.5
Distance of first securing pin from muzzle (on the left) .... do....	17.5
Distance of second securing pin from muzzle (on the right) .... do....	36.0
Distance of third securing pin from muzzle (from above) .... do....	58.5
Distance of fourth securing pin from muzzle (from below) .... do....	77.00
Finished weight of rifle .... pounds..	54,730
Original weight of gun .... pounds..	49,514

11 INCH M. L. RIFLE.

Converted from a 15 in. S.B. Gun by lining with a wrought iron tube and jacket, inserted from the breech.



APPENDIX H[1].

CONSTRUCTION OF A 3-INCH BREECH-LOADING RIFLE.

(Two plates.)

PRELIMINARY REMARKS.

With a view of determining the proper charge to be used in guns of this caliber in service, it was decided to conduct a series of experiments with a 3-inch rifle with varying charges.

The rifle selected for the experiments was altered into a breech-loader to secure that uniformity in recording pressures which the use of a fixed pressure-plug assures; also for the purpose of affording an opportunity of establishing certain facts pertaining to the particular mode of alteration employed, and to give additional tests to the system of construction.

The pressure-plug located (see plate) in the breech-block, is easily removed after each fire, thus supplying a record of maximum pressures at the bottom of the bore.

DESCRIPTION.

Plate I represents in longitudinal section, a 3-inch service wrought-iron gun, cut off at the breech to a length of 63.15 inches, and bored from the breech to receive the steel breech-receiver, which is united to it by a screw-thread.

At a distance of 1.7 inches in rear of the wrought-iron casing, a slot is cut in the breech-receiver for the reception of the breech-block.

Plate II. The steel breech-block is constructed on the sliding-wedge system. The front face is perpendicular to the axis of the bore, while the rear is inclined 1° 30′. The movement is regulated by two guides in the slot, which work in corresponding grooves in the block and are parallel to its rear surface.

The front of the block is hollowed out for the reception of a steel Rodman pressure-plug. The face of the plug performs the functions of an obturator-plate.

The plug differs from the ordinary Rodman construction in the use of rectangular shaped copper pieces, instead of the disks commonly used; also by the plug being opened and closed by a screw-nut at the bottom instead of at the top.

The only mechanism connected with the breech-block is the locking-screw, which is placed in a cylindrical recess at the rear of the block, and locks, when the block is in position, into a female thread cut in the rear face of the slot in the breech-receiver. Two of the three threads of the locking-screw are partially sheared off, in order to allow the connection between the screw and the breech-receiver to be made or broken during the manipulation of the breech-block.

In other respects the breech-block is worked by hand, the wrench of the locking-screw serving as a handle in withdrawing or inserting the block.

As an examination must be made of the pressure-plug after each dis-

charge, no chain or other attachment is used for limiting the outward movement of the block.

The gas-checks used are the ordinary Broadwell rings and the compound steel and copper checks.

RIFLING, CHAMBERING, AND VENTING.

The rifling of the gun is not altered, the original grooves being simply continued along the bore of the steel breech-receiver.

Number of grooves and lands	7
Width of lands	0.5 inch.
Width of grooves	0.846 inch.
Depth of grooves	0.075 inch.

Twist uniform, one turn in 40 calibers.

The chamber is 7.85 inches long and 3.15 inches in diameter. The lands are connected with the chamber by a bevel of 1.1 inches. At the rear the chamber is enlarged to form a recess for the gas-check.

The vent is in a vertical plane passing through the axis, and is at a distance of 1.3 inches from the bottom of the bore.

FABRICATION.

The gun selected for this conversion was 3-inch wrought-iron rifle No. 914, and the work was performed at the West Point Foundery.

The breech-block and breech-receiver were made of Midvale steel. The latter ingot was rough turned and bored, and sent back to the Midvale Works to be tempered in oil.

Specimens were tested from both ingots (before tempering) with the following results:

Specimen.	Area of broken section.	Extension per inch at rupture.	Tenacity per square inch.	
		Inches.	*Pounds.*	
1		0.285	67,593	Breech-receiver.
2		0.270	71,079	Breech-block.

The original gun was first cut off at the breech, bored out, and the screw-thread cut for the reception of the breech-receiver, which was prepared for insertion by boring and cutting the plus thread on its forward end.

The breech-receiver was then screwed into the casing, and secured there by a small steel pin inserted at the joint. It was then finished, bored, chambered, and rifled.

The slot for the breech-block was then cut out in the slotting machine, and finished by hand with the file; and the different parts of the breech mechanism, including the seat for the pressure-plug, were completed and fitted and united.

INSPECTION.

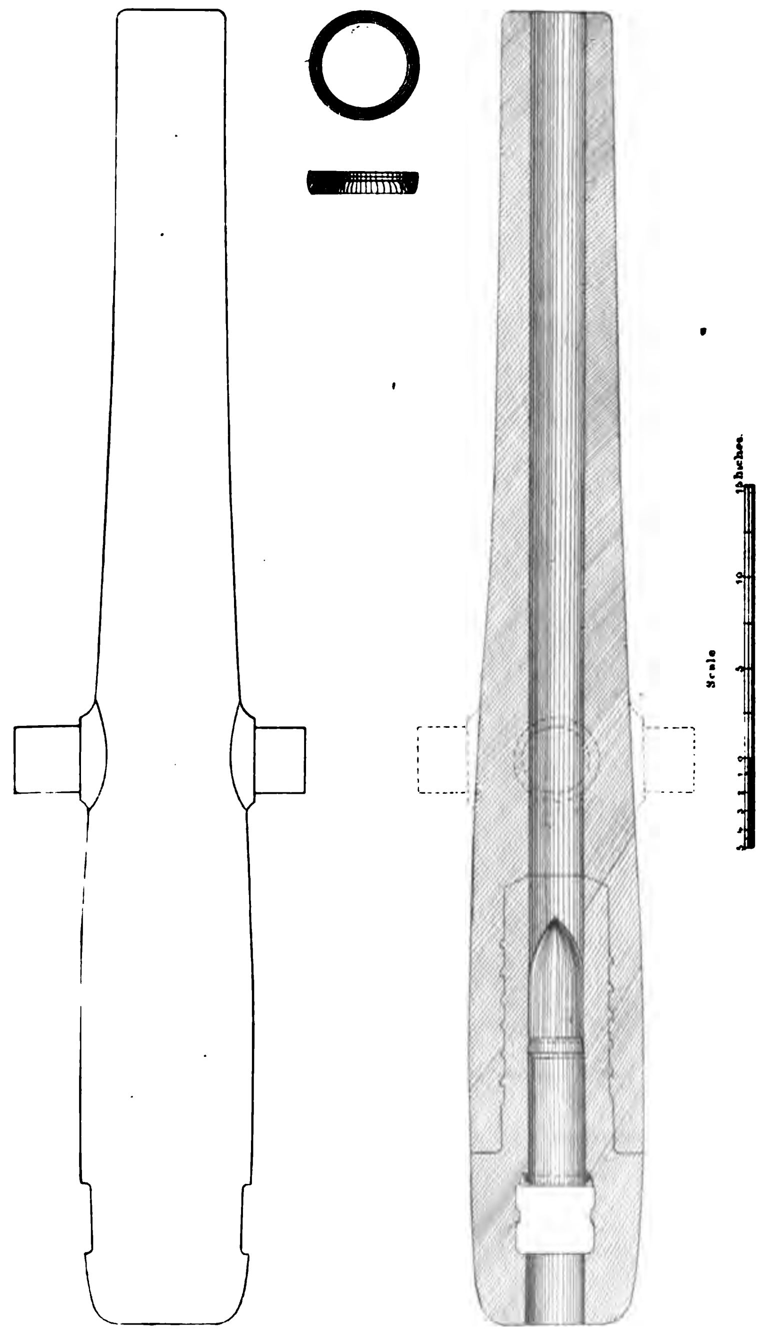
The usual inspections were made of every detail incident to the construction, and the rifle, after completion, accepted as satisfactory, and shipped to Sandy Hook for powder-proof.

Principal dimensions.

Subject of measurement.		Dimensions.
Total length of converted rifle	inches	72. 6
Diameter of bore across lands	do	3. 0
Diameter of chamber	do	3. 15
Diameter of prolongation of bore through breech-block	do	3. 25
Diameter of prolongation of bore in rear of breech-block	do	3. 25
Length of prolongation of bore in rear of breech-block	do	3. 9
Length of breech-receiver in rear of casing	do	9. 5
Total length of breech-receiver	do	24. 938
Diameter of breech-receiver over threads	do	6. 2
Length of screw part of breech-receiver	do	9. 0
Pitch of thread on breech-receiver	do	1. 5
Length of bore	do	64. 8
Length of chamber	do	7. 85
Length of breech-block	do	10. 6
Width of breech-block	do	4. 24
Thickness of breech-block through center	do	3. 8
Width of slot for breech-block { maximum	do	4. 0
Width of slot for breech-block { minimum	do	3. 8
Length of rifled portion of bore	do	57. 15
Number of grooves	do	7. 0
Width of lands	do	0. 5
Width of grooves	do	0. 846
Depth of grooves	do	0. 075
Pitch of rifling, one turn in	feet	10
Weight of breech-block	pounds	36
Weight of rifle	do	844
Preponderance	do	102. 75

PLATE I.

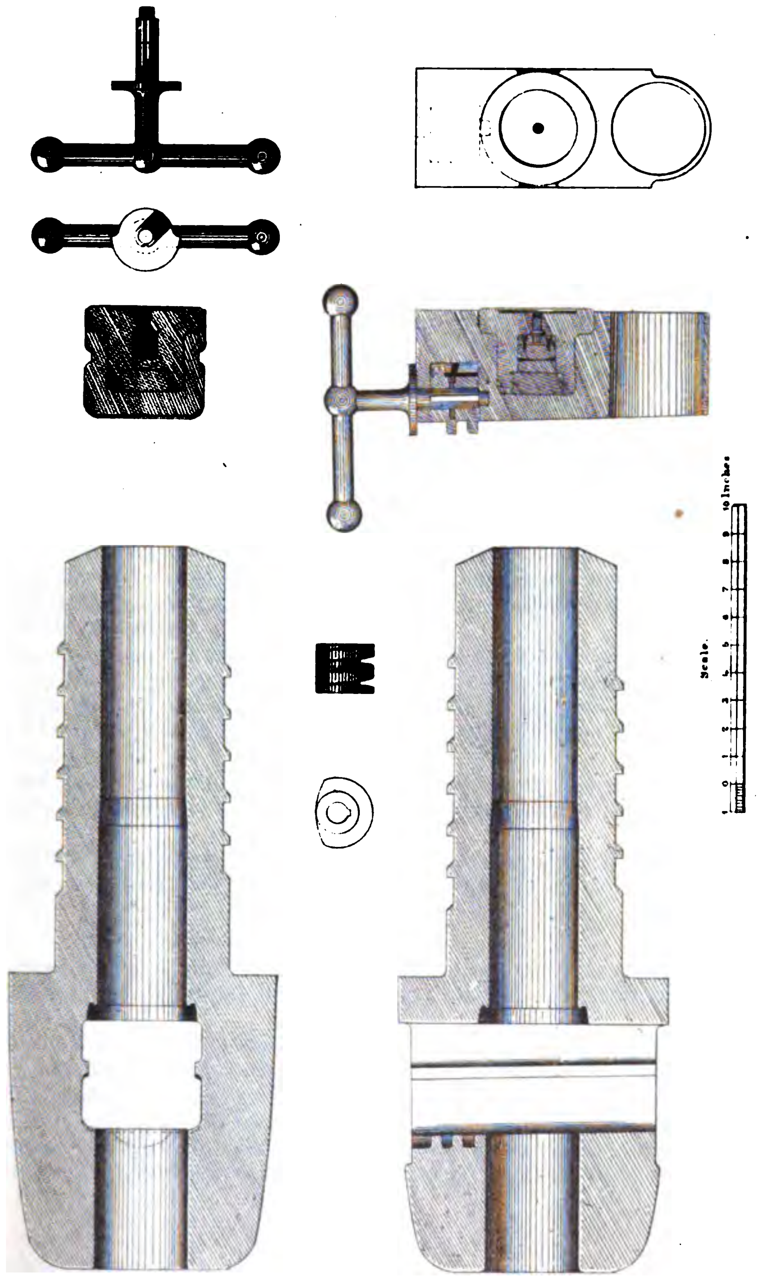
3 INCH B.L. RIFLE.



Appendix H.[1]—Report of Chief of Ordnance, 1879.

3 INCH B.L. RIFLE.

Details.



Appendix H½—Report of Chief of Ordnance, 1879.

APPENDIX H[2].

CONSTRUCTION OF A 3.16-INCH MUZZLE-LOADING RIFLE, CHAMBERED.

(One plate.)

PRELIMINARY REMARKS.

This gun was designed with the view of furnishing the means of a prompt and inexpensive investigation of the advantages of the employment of a powder-chamber larger than the bore, and of increasing the length of the latter. The application of these principles to a larger caliber would have been more satisfactory, but it would have involved a delay which the importance of the subject made it desirable should not occur.

The attention of the department was invited to the subject of chambered rifles in "Ordnance Notes" No. 105, and the principles and probable results discussed in that paper in reference to a proposed 4.5-inch breech-loading rifle.

The same general features then recommended regarding the details of the chamber and length of bore, attain in the altered 3.16-inch rifle.

The bore, it will be seen, is 30 calibers long, and the chamber has a length of 15.04 inches and a diameter of 4.13 inches, and a total capacity of 6.94 pounds of powder.

The capacity of the chamber by volume is 186 cubic inches, and allowing, say, 33 cubic inches per pound of powder, it can accommodate 5.63 pounds. The charge was intended to vary from 5 pounds 5 ounces to 5 pounds 13 ounces, with a projectile varying in weight from 10.5 pounds to 12.5 pounds.

The above-mentioned charges cover cases varying in the employment of from 35 to 32 cubic inches of space per pound of powder in the chamber.

The calculated initial velocity was about 2,000 feet; and the estimated pressure not to exceed, say, 32,000 pounds per square inch.

DESCRIPTION.

Plate I represents a longitudinal section through the axis of the trunnions, showing the principal details of the finished rifle, which are as follows:

The original 3-inch rifle, bored to 3.16 inches, and chambered for a length of 15.04 inches from bottom of bore.

Additional piece screwed to muzzle end of rifle, by which the bore is increased in length from 65 inches to 90 inches.

Reinforcing band, shrunk on body of gun over chamber to increase the tangential strength and correct the muzzle preponderance of the altered rifle.

RIFLING.

The rifling consists of seven lands and grooves.

	Inch.
Width of grooves	0.845
Width of lands	0.5754
Depth of grooves	0.075

Twist uniform, one turn in 10 feet.

VENTING.

The old vent was closed (the copper bushing having been removed) by a wrought-iron screw-plug, and a new one was bored in a vertical plane through the axis of the bore, and at a distance of 6 inches from the bottom of the bore.

FABRICATION.

The gun selected for the alteration was 3-inch wrought-iron rifle No. 820, and the work was performed at the West Point Foundery.

The reinforcing band and muzzle-piece for increasing the length of bore were both made of Ulster iron, of the quality used in the construction of tubes for 8-inch converted rifles. The band was made from a coiled section designed for one of these tubes, and the muzzle-piece forged from scrap iron.

The gun was rough-bored sufficiently to remove all trace of the original rifling, and was then chambered. For this purpose a tool was used similar to, and working on the same principle as, the ordinary rifling tool.

The chamber was first bored, the cut commencing at the bottom of the bore. The body of the gun was then turned down over the chamber, and for a length of 19 inches, to a diameter of 8.907 inches, and the gun subjected to a water-proof of 200 pounds to the square inch. The muzzle was then turned down and a screw thread cut for the reception of the muzzle-piece, which had in the mean time been rough-turned, rough-bored, and prepared for fitting. After the muzzle-piece had been screwed into place, two small pins ⅝ inch long and 0.5 inch diameter were inserted at the joint from either side, and the gun was then finished, bored, and rifled.

The reinforcing band was then shrunk on (shrinkage 0.007 inch), and the original vent having been previously closed, a new vent was bored through the reinforcing band.

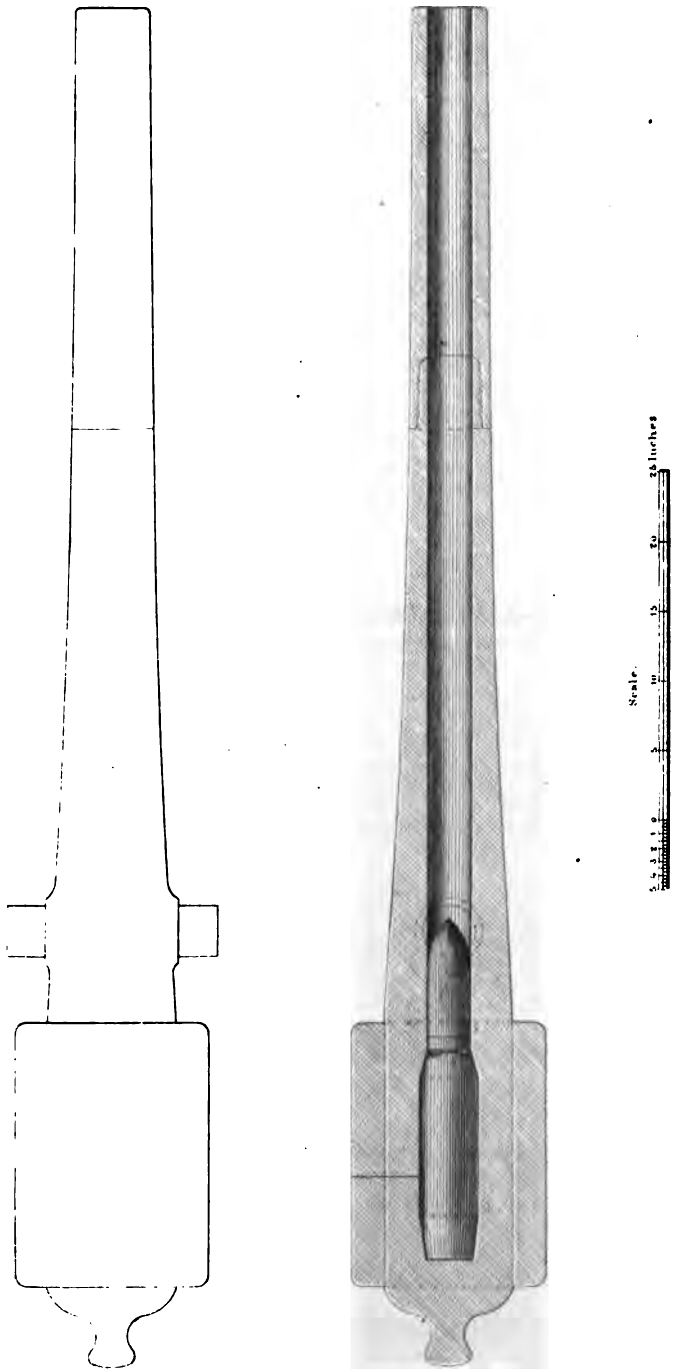
INSPECTION.

The usual inspections were made of every detail incident to the construction, and the rifle, after completion, finally inspected, accepted as satisfactory, and shipped to Sandy Hook for powder-proof.

Principal dimensions.

Subject of measurement.	Dimensions.
Diameter of bore across lands .... inches..	3.162
Length of reinforcing band .... do....	19.00
Interior diameter of reinforcing band .... do ..	8.9
Diameter of rifle under reinforcing band .... do...	8.907
Shrinkage .... do...	.007
Length of bore .... do....	89.91
Length of chamber (including fillets) .... do....	15.04
Diameter of chamber .... do...	4.13
Diameter of bore at bottom of chamber .... do...	3.05
Length of muzzle-piece .... do....	30.28
Weight of rifle .... pounds..	1,285
Preponderance .... do....	66.75

315 INCH M. L. CHAMBERED RIFLE (LENGTHENED)



Appendix H.²—Report of Chief of Ordnance, 1879.

APPENDIX H³.

CONSTRUCTION OF A 3.17-INCH MUZZLE-LOADING RIFLE, RAPID TWIST.

PRELIMINARY REMARKS.

The fact that the use of a shorter twist than now attains in our rifle guns would enable us to successfully use longer projectiles (expanding system) than the present rifling permits, has long been recognized by the Ordnance Board, and the subject has only been delayed by the pressure of other important experiments.

As a preliminary and inexpensive experiment could be made by a change of twist in the 3-inch service rifle, and as the change would probably enable us by trial to secure reliable information on the subject of "shortening our twist" in our heavier guns, a gun of this caliber was altered in accordance with the details given below.

DESCRIPTION.

The alteration consisted only in boring out the lands of the original rifling for the purpose of cutting in the bore a larger number of grooves with a greater twist.

ORIGINAL RIFLING.

Number of lands and grooves	7
Width of lands	0.5 inch.
Width of grooves	0.846 inch.
Depth of grooves	0.075 inch.

Twist, uniform; one turn in 40 calibers.

ALTERED RIFLING.

Number of lands and grooves	13
Width of lands	0.316 inch.
Width of grooves	0.450 inch.
Depth of grooves	0.075 inch.

Twist, uniform; one turn in 24 calibers.

The rifling stops at a distance of 4 inches from the bottom of the bore.

FABRICATION.

The gun selected for this alteration was 3-inch wrought-iron rifle No. 520, and the work was performed at the West Point Foundery.

The gun was placed in the bed and rough-bored till all traces of the original rifling had been removed; it was then fine-bored and rifled.

INSPECTION.

The bore was star-gauged and the details of rifling verified by measurements.

The rifle was then accepted and shipped to Sandy Hook.

APPENDIX H[4].

GAS-CHECKS FOR BREECH-LOADING RIFLES.

(One plate.)

(Composed of a soft and extensible material united to a base made of a hard and elastic material.)

In experiments with the 8-inch breech-loading rifle, both copper and steel gas-checks were used. The former proved the better gas-checks, but at times stuck to the face of the breech-block after firing, to such extent as to make it difficult to withdraw the block. With the steel gas-check, however, no difficulty was found in withdrawing the block after firing, though there was at times a slight escape of gas.

To remedy the defective operation of the checks constructed of a single metal (either copper or steel or other metals), a gas-check was designed and made of steel and copper combined, thus insuring in the ring the hardness and elasticity of steel at the base with the compressibility and extensibility of the copper part in contact with the walls of the gas-ring seat. This construction secures through the extensible copper a perfect and close check at the sides of the seat in the chamber of the gun, while at the same time, the check having its base of hard and unyielding steel, any binding or sticking of the breech fermeture in opening the breech is prevented.

The mode of construction of an 8-inch gas-check is as follows:

Two holes are punched, near either end, through a steel bar about 14 inches long, 2½ inches wide, and ½ inch thick. The bar is then slit with a chisel between these two holes, and the slit first enlarged by a mandrel, and finally formed into a circle on the anvil. It is then placed in the lathe, its bearing surface with the copper finished, and only sufficient excess of metal left elsewhere to allow subsequent slight corrections.

The steel sabot is then carefully heated over a slow charcoal fire until it attains a dull red heat, and is then immersed in a bath of rape oil and left to cool.

A 2-inch round copper bar, 14 inches long, is then similarly shaped into a ring; then placed in the lathe, its face and shoulder which bear against the steel sabot finished, and its interior diameter roughly shaped. Two modes of assembling the two parts have been successfully employed.

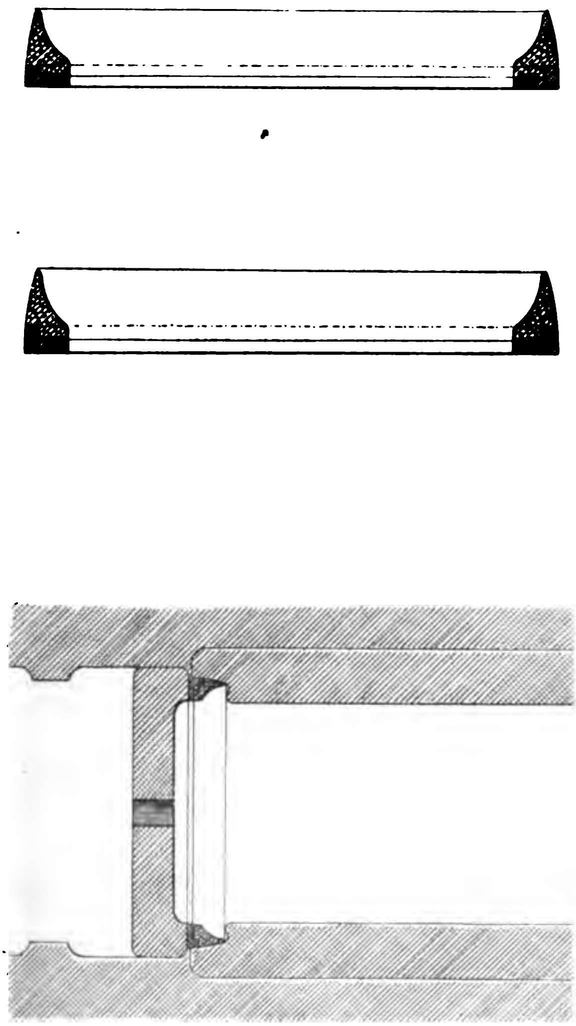
By the first, the copper ring is simply laid in its place upon the steel sabot, and both then placed on a loosely fitting mandrel. The workman then gently hammers the copper ring on the outside, slightly turning both rings after each blow, and so gradually crowds the copper into the recess of the steel sabot.

By the other and preferred mode of assembling, the copper ring is screwed to its steel sabot, as shown in plate.

After assembling, the rings are placed in the lathe, the interior diameter first secured, and the gas-check then otherwise finished.

IMPROVED GAS-CHECK.

(Combination of Copper and Steel.)



APPENDIX H[5].

ALTERATIONS IN 12-INCH RIFLE CARRIAGE.

(One plate.)

These alterations have been made, from time to time, during the present year, as experience proved their necessity, and are as follows:

1st. The most important was made in the chassis, in connection with the traversing arrangement. The operation of throwing the large eccentric-wheels in gear by means only of the ratchet-wheel and lever proved more laborious than was anticipated. As a remedy, a 30-ton hydraulic jack is now suspended between the eccentric-wheels in the following manner: An iron plate is attached by two arms to the chassis, with space enough between it and the chassis to contain a heavy rubber spring. On the under side of this plate rests the head of the jack, which is supported a short distance above the platform by an iron strap, which, passing over the rubber spring, is attached to the cylinder of the jack on either side. When the jack is released, after the chassis is in gear, the spring raises it off the platform.

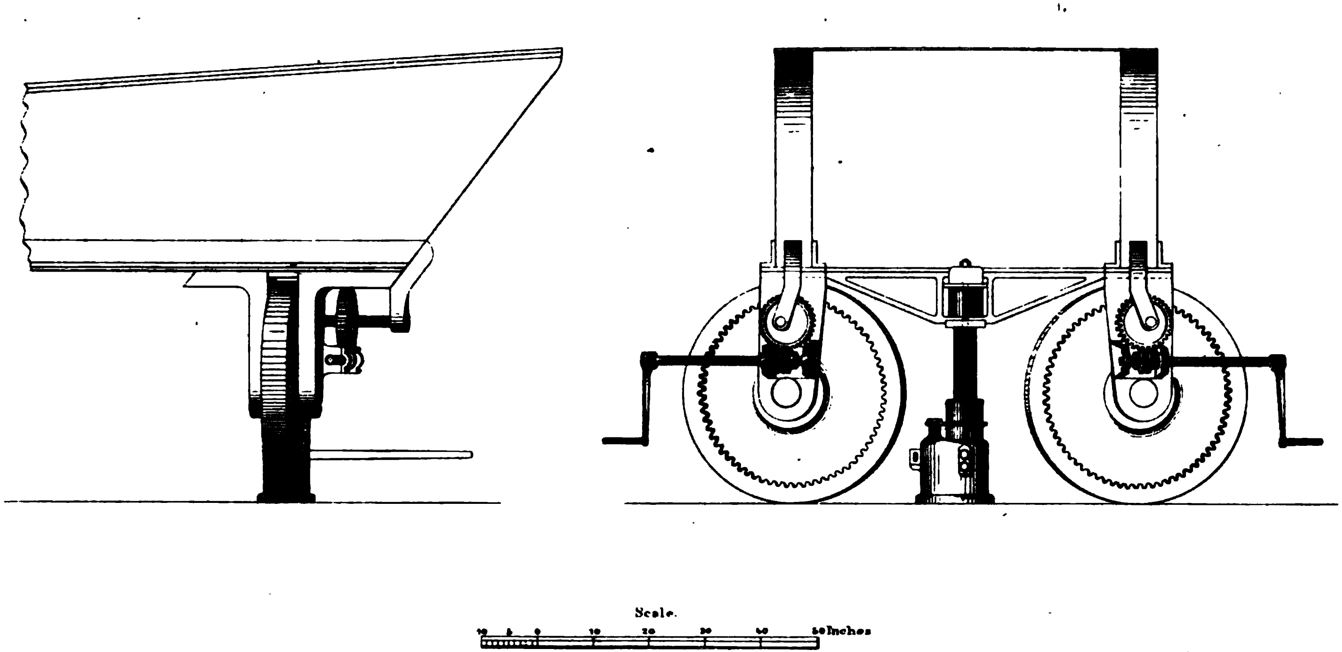
2d. Worm-gear has been added to increase the power of the rack and pinion movement first used for traversing.

3d. The power of the worm-gear used for throwing the rear eccentric-wheels of the top carriage in gear has also been increased.

4th. The maneuvering drums used in drill for running the gun "from battery" have been increased in width.

5th. The levers of the movable couplings have now an attachment for securing them to the side of the chassis. It was found that without them the jar upon the levers, after firing, was sometimes sufficient to throw the coupling out of gear.

ALTERATION IN TRAVERSE WHEEL GEARING ON 12 INCH CARRIAGE.



APPENDIX H[6].

PROPOSED CHAMBERED RIFLE, 4.50-INCH CALIBER.

(Four plates.)

FEBRUARY 24, 1879.

I have the honor to inclose herewith a description of a proposed breech-loading 4½-inch chambered rifle, accompanied by the necessary drawings showing the details of the construction.

As it is deemed important that the subject of chambering guns should be investigated at an early date, the inclosed plans and data regarding them are submitted for the consideration and action of the department. The cost, it is approximately estimated, will not exceed, say, two thousand dollars.

As a fact of some interest in connection with the subject of employing air-spaces with powder charges, or the introduction of powder chambers larger than the bore of the gun, the attention of the department is invited to the following extract, taken from a paper obtained from the Confederate archives at Richmond, Va., dated 1864:

> A 7-inch gun was loaded with a full charge of powder, made up in a cartridge only 6 inches in diameter, and so supported in the bore that a stratum of air half-inch in thickness remained between the cartridge and the walls of the chase. The shot was in immediate contact with the powder. The result of the experiment was that, while the shot retained its full initial velocity, the strain on the gun was reduced nearly one-half. The stratum of air between the cartridge and the surface of the charge evidently acted the part of a cushion or spring, absorbing a greater portion of the initial strain in its compression, the wave of transmitted force being unable to pass through it with sufficient velocity to affect the gun materially.

In conclusion, I may state that the subject of the proper kind of powders, the size of grain, and densities for 4½-inch siege rifles, chambered and unchambered, is now under advisement and some samples in course of fabrication.

APRIL 29, 1879.

Referring to my communication of February 24, 1879, submitting a description and drawings of a proposed 4½-inch breech-loading chambered rifle, I have now to inform you that I have prepared a modified plan of construction for this gun, involving some new features in the mode of construction, and some changes in dimensions. This modified plan is herewith submitted (marked Plate IV) for consideration, in connection with the originals referred to above.

Referring to Plate I, accompanying my letter of February 24, it will be seen that a coiled wrought-iron tube affords the bore-surfaces for some distance in that construction. This feature, on further consideration, it is thought, in a gun of so small a caliber, can be dispensed with; and as its absence will enable us to increase the diameter of the chamber and thus reduce its length—the thickness of the wrought-iron walls preventing any change in this direction—an additional length of bore beyond the chamber can be secured.

A reference to the legend (Plate IV) will show the changes in the dimensions of the chamber, resulting from the absence of the coiled

wrought-iron lining tube. In large constructions, of course, the thickness of walls of the wrought-iron lining will afford all the latitude necessary for the diametrical dimensions of the chamber.

It will be observed that in the proposed construction—using steel altogether—the steel breech-receiver is lengthened so as to replace fully the coiled wrought-iron lining contemplated in plan shown on Plate I. The other features of the construction remain the same as are shown on Plate I.

The legends give all the necessary information as to dimensions, charge, velocity, power, &c., of the proposed construction.

DESCRIPTION.

The highly satisfactory results which have attended the experiments made by Sir William Armstrong in the applications of chambers to 6-inch and 8-inch rifles have led to the consideration of the subject of the construction of an experimental gun embodying this feature, with a view to a series of tests which shall enable us to form accurate conclusions as to the value of the idea of chambering; and also affords sufficient data to enable us to undertake its application, if successful, to guns of large calibers for seige and seacoast armament.

With a view to economy—the capacities of existing plants for production, and the securement of the gun at an early date—it has been decided to recommend a 4½-inch siege-rifle, and to make it a breech-loader, using the round wedge *fermeture.*

The introduction of the latter feature, it is thought, will secure a more perfect application of the principles proposed to be investigated; give greater facilities for modifications and alterations if found necessary or deemed desirable, while further developing the question of the value of breech-loading constructions and systems.

The general features are a cast-iron body lined partly by a wrought-iron tube, and having a steel breech-receiver inserted at the rear, screwed to the cast-iron body, and protruding sufficiently to the rear to accommodate the round wedge *fermeture.* The cast-iron body is *fretted* with a single series of steel rings from its rear end to a short distance in front of the trunnions.

The trunnion-ring is a band of steel cast and forged solid, and then cut out and reduced to the proper dimensions. It is intended to be shrunk on under ordinary tension, the cast-iron being recessed for the purpose. A bisected ring (shown in section in drawing) finds place in front of the first *frette* in front of the trunnions, and, fitting into a recess on the cast-iron body, gives additional security for preventing a forward movement of the trunnion-band.

The steel jacket breech-receiver is shrunk on the wrought-iron tube, and the two so united inserted into the cast-iron body under shrinkage; the mode of construction in this regard being identical with that followed in the fabrication of the 8-inch breech-loading rifle recently made at the South Boston foundery.

A steel ring is superimposed on the two rear *frettes,* to give additional strength as well as finish to the system.

The steel *frettes,* it is intended, shall be put on under shrinkage, after the simple manner of the shrinkage of tires on ordinary wheels; the *frettes* being raised to a black heat, and when placed in position on the cast-iron body cooled by converging jets of water emanating from a water collar placed externally over and concentrically with each *frette* in turn. The thickness of wall at the chamber is over 1¼ calibers, and is deemed

sufficiently strong tangentially, constructed as it is of wrought iron, steel and cast iron.

It is deemed important to keep up the tangential strength of the system to a considerable distance beyond the seat of the charge, as the circumstances of inflammation and subsequent combustion of it (large in weight) would seem to demand a considerable length of bore of the maximum strength, as pressures approximating to the maximum must attain longer than in ordinary cases; or, to illustrate otherwise, the curve of pressure must be relatively much flatter than that attaining in the use of a common charge. Also, it is believed that the action, in the case of the employment of chambers with large charges of powder, results, at the time of the initial inflammation of the charge, in the development of a powder-gas comparatively low in pressures, owing to the space above, but sufficient, however, with the compressed air, to start the projectile with a low velocity; and that when the maximum pressures attain, the volume of the bore between the burning powder andprojectile is relatively greater than under ordinary circumstances, and that the phenomena of a rapidly augmenting gas evolution, giving increased power, ensues, but, owing to the rapidly increasing velocity of the projectile increasing rapidly the bore-spaces between the burning powder and the shot, the resulting pressures decline *gradually* from the maximum (not usually dangerous), and hence with long bores the capability of thorough consumption of large charges with moderate pressures resulting, and with high initial velocities, are within our reach. It is, therefore, surmised that the practical points sought to be gained by the multicharge gun-system of Lyman are probably secured by the introduction of a chamber larger than the bore, and in the simplest and most practical form.

The details of the Armstrong 8-inch rifle show a chamber of the same form as that proposed in this case. The length is 4.78 calibers, and the diameter of the cylindrical part is 10.5 inches. The charge is 95 pounds, and weight of projectile 180 pounds. The calculation is to secure 32.5 cubic inches of space to every pound of powder, and the dimensions of the chamber have been determined accordingly.

A length of bore (proper) of 21.22 calibers it is intended shall insure a volume which will practically utilize the entire charge, and give the maximum velocity practically attainable.

From analogy, using the above details, the features of the chamber and length of bore in the proposed 4½-inch rifle have been deduced. The weight of charge in both cases is about one-half the weight of the projectile, and the dimensions of the chamber of the 4½-inch regulated to give a space of 32.5 cubic inches to each pound of a charge of 17 pounds. (See Plate I.)

In order to insure the maximum velocity presumed to be practically attainable, the gun has been given a length of 30 calibers instead of 26, as used by Sir William Armstrong.

In this connection reference may be had to the results recently attained at Sandy Hook, in the employment of comparatively high charges of experimental powders used in the standard 4½-inch rifle. The ordinary charge of 3¼ pounds of powder of a granulation of 1,550 grains per pound and density of 1.755 gives a mean average of, say, 1,300 feet initial velocity, with a mean pressure of 23,000 pounds; while a smaller grained powder, 3,038 grains per pound, but greater in density (1.778), using 5-pound charges, gives a mean velocity of, say, 1,578 feet, and a pressure of, say, 27,500 pounds. In both cases the projectile weighs 25 pounds.

It is evident from this record that the *kinds* of powders employed will constitute important factors in the results, and that proper powders,

used with sufficient length of bore (even without the use of chambers), will largely contribute to success in the attainment of comparatively high velocities, attended with reasonable and safe pressures.

Attention is invited to the accompanying table, prepared by Lieut. Charles S. Smith, comparing the dimensions of the Armstrong muzzle-loading 8-inch chambered rifle with the proposed dimensions for the proposed 4½-inch siege rifle.

The accompanying plates show the gun in longitudinal section and in elevation. Plate III shows a modification by turning down the chase to diminish the weight. This latter element is beyond what is desirable; but it is not seen that it can be judiciously reduced, especially in an experimental rifle, without incurring some possible risk as to strength for all the purposes for which it may be deemed necessary to use it.

Reference may be here made to the fact that a study was made of our present 4½-inch cast-iron siege rifle, with a view of chambering it for the proposed tests; but a careful examination showed that it would probably be too light, and that the difference between cost of alteration and a new gun would not be sufficient to justify the utilization of a gun not fully meeting the requirements of the situation.

Table of comparison between the Armstrong 8-inch muzzle-loading and the United States 4½-inch experimental rifles, chambered for large charges.

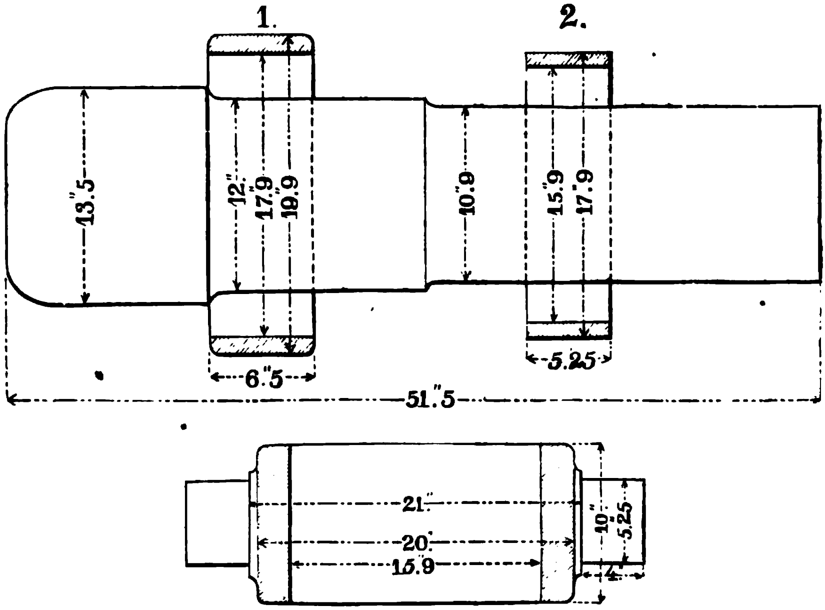
Nature of gun.	Weight.	Diameter of bore.	Diameter of chamber.	Ratio of diameter of bore to diameter of chamber.	Length of chamber, in calibers.	Length of rifled part of bore, in calibers.	Total length of bore, in calibers.	Diameter of cartridge, allowing 32.5 cubic inches per pound of powder.	Weight of projectile, pounds.	Full capacity of chamber. Cubic inches.	Full capacity of chamber. Powder, pounds.	Charge, allowing 32.5 cubic inches per pound of powder.	Ratio of weight of charge to weight of projectile.	Ratio of weight of projectile to weight of piece.	Initial velocity.	Mean pressure, pounds.	Thickness of wall of gun in rear of trunnions, in calibers.
Armstrong 8" muzzle-loading rifle.	11 tons 9 cwt......	8"	10".5	1.3125	4.78	21.22	26	9.2	180	3,088	121	95	1 to 1.9	1 to 142	2,100	37,000	1.5
United States 4½" breech-loading experimental rifle.	7,334 pounds = 65 cwt.	4½"	5".90	1.311	4.88	25.11	30	5.2	32.5	552	20	17	1 to 1.9	1 to 225	*2,014	....	1.5

*Calculated.

The above velocity of 2,014 feet for the 4½" breech-loading experimental rifle was determined by a calculation based upon the "factor of effect" obtained with the service 4½" muzzle-loading rifle. It is highly probable that with powders of higher density and coarser granulation, specially adapted to the chambered gun, a considerable increase in the velocity, as well as in the "factor of effect," will result.

Proposed method of fabricating steel parts for 4½″ breech-loading rifle. Extracts from Lieutenant C. W. Whipple's report on the character of plant, capacity of works, &c., of the "Midvale Steel Works," Nicetown, Pa.

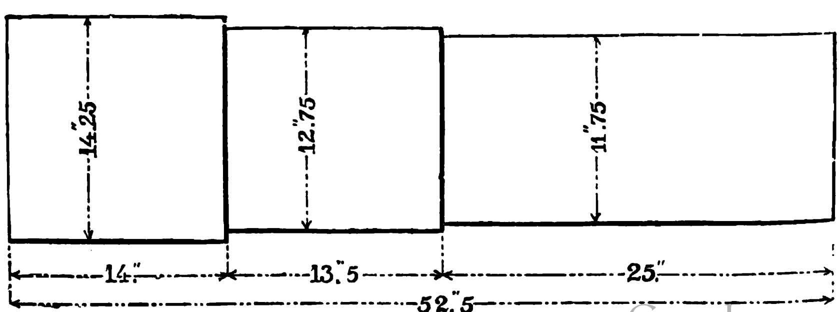
The following sketch shows the finished dimensions of the different steel parts required for the conversion of a 4½″ muzzle-loading rifle into a breech-loading chambered rifle:



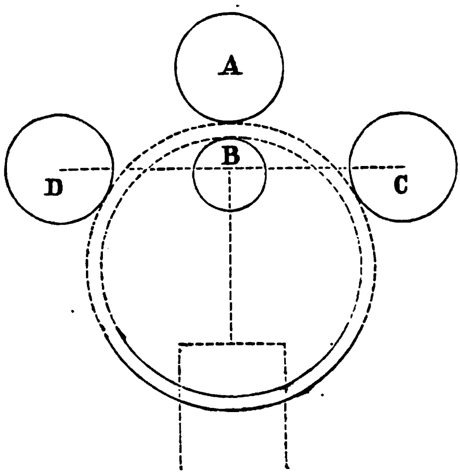
	Pounds.
Breech-receiver (solid), approximate weight	1,600
Ring 1, approximate weight	110
Ring 2, approximate weight	80
Trunnion-ring	386

It is proposed to make the different parts as follows:

The breech-receiver would be forged without difficulty from about a 24-inch ingot, hammered to the shape and dimensions shown in the following sketch. Six inches would be added to the length, however, to furnish specimens for test. The ingot would then be rough turned and bored, and tempered in oil.



Rings 1 *and* 2.—Were these to be made in numbers sufficient to warrant the alteration in the rolls, that method would be employed in their construction which is used in rolling "tires." Consequently a description of this method is given:



Four rolls are made to revolve about vertical axes. A is called the "main roll," and is the one which shapes the flange upon the tire. It has no movement except that of rotation. B is the "pressure-roll," which is attached to the piston of a hydraulic press and serves to force the tire against the "main-roll." C and D are the "guide-rolls," which keep the tire round and prevent it from "buckling." These latter can be moved to or from each other by means of gearing.

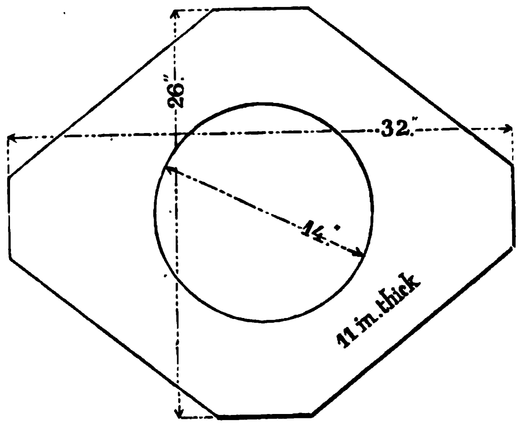
A square ingot of the proper weight, and with its edges rounded, is first flattened under the hammer to the proper thickness, and a hole punched through the center of it; after being raised in a furnace to a red heat it is taken out and slipped over the "pressure-roll." One workman, who stands by the lever controlling the hydraulic press, signals to the engineer on the floor beneath to start the rolls, and regulates the "pressure-roll"; another, standing just in rear of the "main-roll," moves, by means of a screw, the friction-rolls gradually apart as the tire enlarges; while a third workman, from time to time, gauges the exterior diameter with an iron bar.

Tires are made in sets of four, and are guaranteed not to differ from each other in outer circumference more than $\frac{1}{8}$ of an inch. After being rolled they are bored, but as it is ordinarily prescribed that no metal shall be turned off from the outside, the operation of rolling so as to keep within the prescribed limits is a nice one.

As it happens that no rolls of the proper size are on hand, the following process, often employed, would be used in making rings 1 and 2.

The ingot would be flattened and punched, as described above. The ring thus formed would be placed on the horn of an anvil and beaten out to the proper size. The hammer used for this work is automatic, and strikes at the rate of thirty or forty blows a minute, and there is an automatic attachment for slightly shifting the ring upon the anvil after each blow. These rings can be so furnished that not more than $\frac{1}{4}$ to $\frac{5}{16}$ of an inch will have to be taken off in finishing.

Trunnion-ring.—The shape of the ring prevents its being rolled or hammered out on the anvil. It is proposed to make it as follows:



A square ingot with rounded edges will be flattened to a thickness of 11 inches, and then shaped as shown in above sketch, not by hammering, but by cutting away the surplus metal. A hole will then be punched through the center, with a diameter almost as large as the required diameter. It will then be moderately hammered on its eight faces, and the rest of the work must be done in the lathe.

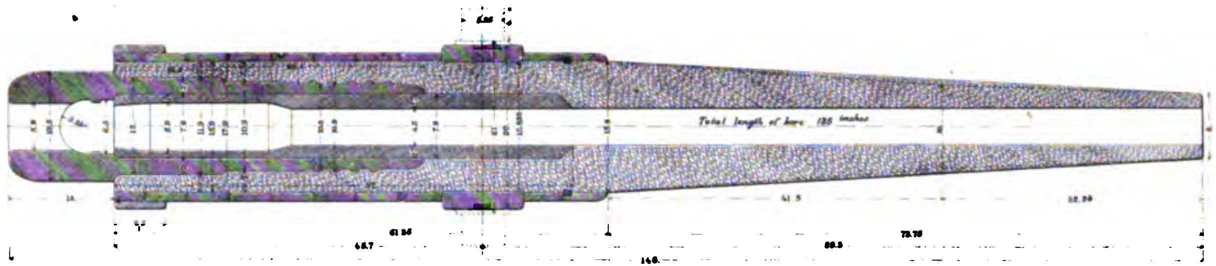
The plant of the Midvale Steel Works consists of one large converting furnace, not now in use; a large crucible furnace, used to a limited extent for the production of small ingots; a small Pausard gas-furnace; and two Martin-Siemens furnaces. Of the latter, the smaller has a nominal capacity of 5 tons, or 15 tons in 24 hours, but a single casting can be obtained from it of 6 tons weight; the capacity of the larger furnace, which has recently been built, is stated to be about 30,000 pounds.

All of the hammers at the works are double action; the heaviest weighs 7 tons.

The tempering process, as applied to ingots suitable for gun constructions, consists in heating the hammered and rough-finished ingot to a temperature varying between dull and bright cherry heat, and then plunging it into the oil bath; finally, when the inside of the ingot, after being removed from the bath, shows a dull red heat only discernable in a darkened room, it is placed in a furnace of about the same temperature and allowed slowly to cool. The ingot is not subjected to this process with the intention of strengthening or toughening it, but solely for the purpose of securing more uniformity in its structure.

PROPOSED 4½ INCH B.L. CHAMBERED RIFLE.

Section.



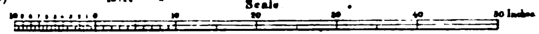
Legend.

Length of chamber.	4.88	cals.
" " rifled part of bore	25.1	"
Total length of bore.	30.	"
Number of cubic inches in chamber.	381.7	
Capacity of chamber	19.5	lbs.
Charge allowing 22.5 cubic inches per pound of powder.	17.	"
Weight of projectile.	32.5	"
Initial velocity	2014.	feet
Energy per inch of shot circumference	64.04	foot tons
" " square inch of shot cross section	87.46	" "

Penetration

By Noble's Formula	7.59	inches.
" Maitland's " (with chilled heads)	12.14	"

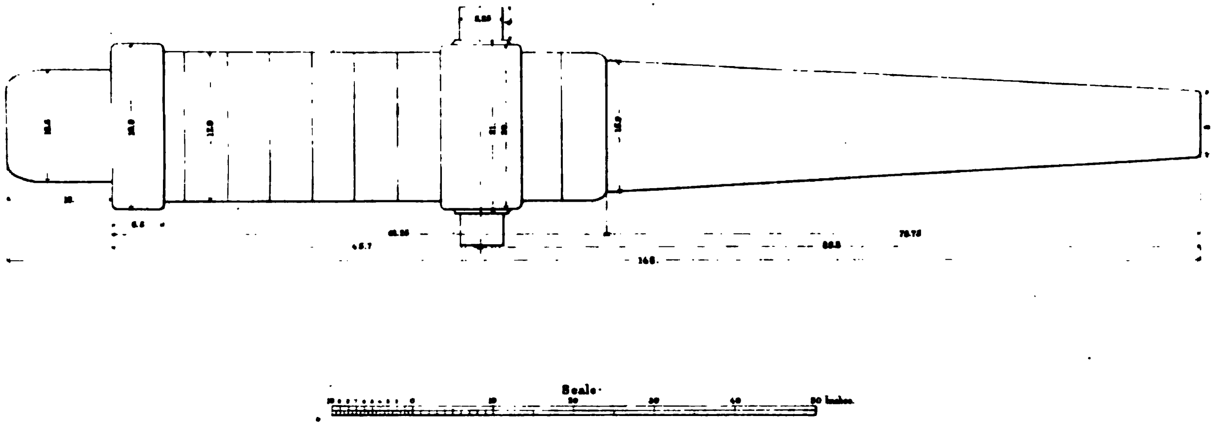
Scale



Estimated weight 6500 lbs.

PROPOSED 4½ INCH B.L. CHAMBERED RIFLE.

Plan.

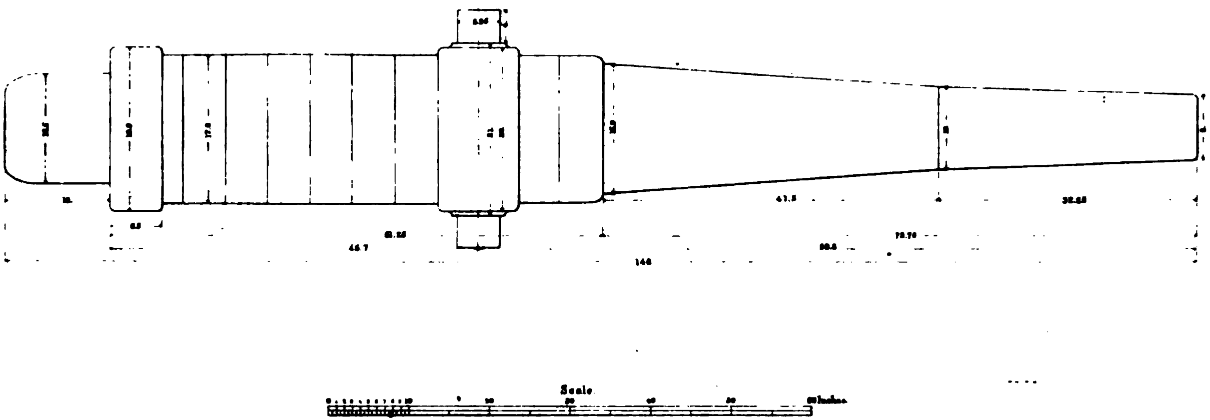


Estimated weight 6500 lbs.

PLATE III.

PROPOSED 4½ INCH B. L. CHAMBERED RIFLE.

Plan.



Estimated weight 6250 lbs.

PROPOSED 4½ INCH B.L. CHAMBERED RIFLE.

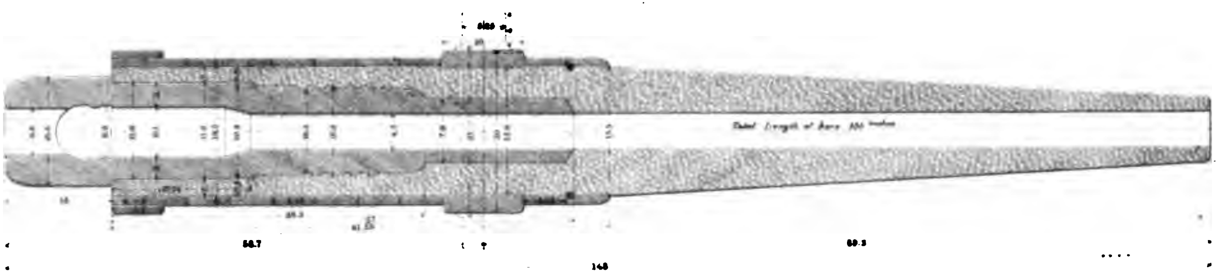
Weight of cast iron body	3838	lbs
" " breech block recess and breech block	1284	"
Jacket, trunnions & breech band	1286	"
Total weight of gun	6408	"

Scale

10 0 10 20 30 40 50 inches

Weight of single hoops	79	lbs
" " breech band	110	"
" " trunnion hoops with trunnions	300	"

Section.



Legend.

Length of chamber	3.77	cals
" " rifled part of bore	25.1	"
Total length of bore	30.	"
Number of cubic inches in chamber	581.7	
Capacity of chamber	10.5	lbs
Charge allowing 32.8 cubic inches per pound of powder	17.	"
Weight of projectile	52.5	"
Initial velocity	2014	feet
Energy per inch of shot circumference	64.06	foot tons
" " square inch of shot cross section	57.46	" "

Penetration.

By Noble's Formula	7.59	inches
" Maitland's " (with chilled heads)	12.16	"
Estimated weight	6405	lbs

Appendix H⁶.—Report of Chief of Ordnance, 1879.

APPENDIX H 7.

REPORT ON EXPERIMENTAL CANNON POWDERS, CAPT. C. S. SMITH, ORDNANCE DEPARTMENT.

(One plate.)

EXPERIMENTAL CANNON POWDERS.

With a view to the improvement of powders for cannon, and of ascertaining the most suitable density, form, and size of grain for each existing service caliber, various experimental powders have been procured, from time to time, and tested at the Sandy Hook proving-ground.

The following is a brief description, as regards their nature, mode of fabrication, and ballistic properties, of such experimental powders.

Hexagonal Powders.—A powder of this class having given excellent results in the trial and proof of the 8-inch experimental rifles, it was adopted for the service 8-inch rifles. A description of the powder is given in the Report of the Ordnance Board on the trial of 8-inch rifle converted, No. 1, and published in the Report of the Chief of Ordnance for 1875. It is a molded powder of the form shown in the plate, Fig. 2, and for the service 8-inch rifles has a density of 1.75; the granulation, or number of granules to the pound, being 72.

The average results obtained with this powder are as follows;

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
8-inch rifle, converted	Hexagonal (E. V. type), standard.	35	180	1,344	29,775

The experimental hexagonal powders manufactured for the 10, 11, and 12.25 inch rifles were of coarser granulation and of higher density than the above, but were identical as to form and mode of fabrication.

These powders were as follows:

	Density.	Granulation.
F. P. hexagonal powder	1.785	67
S. R. hexagonal powder	1.780	50
H. S. hexagonal powder	1.80	50
G. hexagonal powder	1.77	40
H. hexagonal powder	1.80	40

The mean results obtained with the F. P. powders with the different calibers are as follows:

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Initial velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
8-inch rifle	Hexagonal F. P. type	35	180	1,337	26,714
10-inch rifle	......do	70	400	1,389	22,622
	......do	80	....	1,430	23,833
11-inch rifle	......do	70	504	1,275	35,000
12.25-inch rifle	......do	115	700	1,485	33,500

The H. R. and H. S. powders have been tried only in the 11-inch rifle. The results obtained were not as satisfactory as were to be expected, and it was thought that they were largely influenced by the existing atmospheric conditions at the time of trial.

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectiles.	Velocity at 110 feet.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
11-inch rifle	H. R. hexagonal	70	505	1,294	35,000
	H. G. hexagonal	75	505	1,318	34,000

The firing of the F. P. powder in this rifle took place at the same time as the above, and it will be observed how inferior are the results to those obtained with the same powder in the 10 and 12.25-inch rifles. The charge with H. S. powder could probably have been increased to 80 pounds, but the sample was exhausted before this weight could be tried.

The I. G. and I. H. powders have but just been received and have not as yet been tested.

A hexagonal powder (I. C.) of granulation 72, and density 1.70, was ordered expressly for the 3.17-inch chambered rifle. The results obtained, though fair, were not so satisfactory as those obtained with another powder (see further on).

The mean results obtained with I. C. powder are as follows:

Nature of gun.	Kind of powder.	Weight of charge.		Weight of projectile.		Velocity at 81 feet.	Pressure.
		Lbs.	*Ozs.*	*Lbs.*	*Ozs.*		
3.17-inch rifle, chambered	I. C. hexagonal	5	7½	10	6	1.881	23,000

SPHERO-HEXAGONAL POWDERS.

These are molded powders, the grains differing from the ordinary hexagonal powder by being formed of two hemispheres, instead of two pyramidal frustums united upon a hexagonal zone or base (Fig. 3). It was thought that the nearly spherical form of the grains would insure very uniform results.

The granulation was the same for all, viz, 123 to the pound, but the density varied as follows:

	Density.
H. A.	1.75
H. B.	1.73
H. C.	1.72

These powders were tested in the 8-inch rifle converted in 1876; the best results being obtained with H. A., as follows:

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
8-inch rifle, converted	H. A. sphero-hexagonal	35	180	1,428	32,875

Contrary to expectation, the results obtained with the H. B. and H C. powders, which from their lower densities should be quicker-burning powders, were much inferior to the above, as regards both pressure and velocity. A sphero-hexagonal powder, I. B., of density 1.728, and granulation 123, was employed in the recent experiments with the 3.17-inch chambered rifle (see report of the Ordnance Board on trial of 3.17-inch rifle), and with excellent results.

The following is a mean summary with the maximum charge employed:

Nature of gun.	Kind of powder.	Weight of charge.		Weight of projectile.		Initial velocity.	Pressure.
		Lbs.	*Ozs.*	*Lbs.*	*Ozs.*		
3.17-inch chambered rifle	I. B. sphero-hexagonal	5	13	10	8	2,026	30,000

The amount of air-space allowed in the chamber with the above charge was about 32 cubic inches per pound of powder.

SQUARE POWDERS.

The grain is formed of two quadrangular pyramidal frustums united on a square base (Fig. 9). The side of this base is about 1.25 inches, and the thickness of the grain 1.30 inches.

These powders were intended as experimental powders for large calibers, and were made of three different densities, but of the same granulation, viz:

	Granulation.	Density.
G. S.	11	1.775
G. T.	11	1.760
G. W	11	1.715

The tests were made in the 11-inch rifle, using as high as 85 pounds of G. S., with a 505-pound projectile. The results demonstrated that the density of the G. S. was too high for the granulation. G. W. proved too violent owing to its low density, even with the moderate charge of 70 pounds.

The results obtained with G. T. were as follows:

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Velocity at 110 feet.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	
11-inch rifle	G. T., square	70	505	1,245	31,500
		75	505	1,314	33,000

These results, though only fair, yet indicate that the charge might safely be increased to 80 pounds, with the promise of much better results; since for an increase of 5 pounds, *i. e.*, from 70 to 75, the velocity has been increased 71 feet, while the pressure, on the other hand, has run up only 1,500 pounds.

SCHAGHTICOKE POLYHEDRAL POWDER.

This powder (Fig. 8.) is thus described by Commander Marvin, U. S. N.:

It is granulated from properly compressed ordinary press-cake in the following way: The cake is placed on a movable table or form, which is made to pass between two pairs of rollers. A set or comb of stationary cutters meets the cake on its passage and marks a series of grooves on its surface. By turning the cake half-way around, it is marked out into squares on a second passage. This process applied to the reverse face gives it a similar character, and determines the planes of fracture along which the cake will break up to form the grains.

As tested in the 8-inch rifle in the 1876 (see Report of the Chief of Ordnance for 1877) the following results were obtained; the density of the powder being 1.784 and the granulation 74:

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
8-inch rifle	Polyhedral. Laflin & Rand	35	180	1,360	37,500

HAZARD'S CUBICAL POWDER.

This powder is of a regular cubical grain (Fig. 7), being formed by cutting the press-cake in two directions at right angles to each other by means of saws. A sample was tested in the 8-inch rifle in 1876 (see Report of the Chief of Ordnance for 1876 and 1877), with the following results:

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
8-inch rifle	Hazard's cubical. D=1.765. G=56.	35	176	1,446	46,500
9-inch rifle	Hazard's cubical, D=1.765. G=56	40	229	1,436	24,750

As tested in the 11-inch rifle, this powder proved "high," a pressure of 28,000 pounds resulting with a charge of only 50 pounds.

ENGLISH PEBBLE POWDER.

The very much cheaper production of pebble powder, as compared with molded powders, as well as the good results obtained with this powder in England, in guns of large caliber, led to the trial of this powder in 1877. (See Report of the Chief of Ordnance for 1877.)

The powder employed was obtained from Pigou, Welks & Laurence, London, and consisted of three samples, of the same granulation, viz, 140 to the pound, but of different densities, namely, 1.736, 1.749, and 1.756. The results were not very satisfactory, the pressures being high.

The best result was obtained with the highest density, which for a 35-pound charge and 180-pound projectile gave 1,377 feet velocity and 38,333 pounds pressure.

Pebble powder is formed by cutting the press-cake in two directions at right angles, by means of rollers having straight cutting edges arranged along their surfaces; the sharp edges and angles being removed in the subsequent process of glazing. With a coarse granulation, the general form of the grain is cubical, but with the granulation given above it is very similar to mammoth powder.

PROGRESSIVE POWDER.

(Figs. 4, 5, 6.)

The excellent results obtained in Italy with what was termed "progressive powder"—a compound powder made up by pressing together a powder of high, with a powder of low density—suggested the advisability of making trials of similar powders in some of the larger calibers at Sandy Hook. The Messrs. Du Pont were accordingly directed to manufacture three samples of five barrels each, after the following instructions:

1st. Make a grain powder with grains varying in size (irregular in shape) from 0.3-inch to 0.6-inch.

2d. Mix these grains with mealed powder in the proportion of 60 per cent. of grain to 40 per cent. of mealed powder, and press the mass into cakes, which should have a density of about 1.75; the cakes being of two thicknesses, the thinner of ordinary mammoth powder size.

3d. Break the thinner cakes into irregular grains of the same size as service mammoth powder, and the thick cakes into cubes, or approximate shapes thereto, whose edges shall be respectively 1 inch and 1½ inches.

In explanation of the above, the following remarks were added in regard to the mode of fabrication, action of powder in the gun, &c.:

After passing through the first stage of manufacture, and being brought to the condition of mealed powder, it is pressed into cakes which have a density of 1.79; the cake is broken up into irregular grains of from 0.3-inch to 0.6-inch in thickness, as stated above, which are not to be glazed. These grains are mixed with 40 per cent. of mealed powder, taken from the same working as that from which the grains themselves are made, and the whole mass pressed into a cake having a less density than the original small grains, say 1.75. The cake is then granulated as above prescribed.

Each grain of the resulting powder is thus a conglomerate grain, consisting of one or more small grains of very dense powder imbedded in a mass of less density, the mean density being 1.75.

The theory of the combustion of this powder is that the powder of less density being more quickly consumed, the whole charge breaks up into a much greater number of smaller grains, thereby exposing a greatly increased surface to the action of the flame.

In using this powder that size of the regular-shaped grains is employed most suitable to the caliber of the gun, and is mixed with a certain proportion, to be determined by experiment, of the powder of irregular or mammoth grain.

The above samples have been received at the proving-ground, but have not as yet been tested.

POWDERS FOR 4.5-INCH SIEGE RIFLE.

In order to increase to a more adequate degree the power of this piece, it was desired to procure a powder which should admit of using a charge of from 7 to 8 pounds, with a projectile of from 32.5 to 35 pounds, without overstraining the walls of the gun.

A number of powders were procured from the Messrs. Du Pont and tried by the Ordnance Board. These powders were all of irregular granulation, but differed as to size of grain and density.

The best results obtained were as follows:

Nature of gun.	Kind of powder.	Weight of charge.		Weight of projectile.	Velocity, instrumental.	Pressure.
		Lbs.	*Ozs.*	*Lbs.*	*Feet.*	*Lbs.*
4.5-inch siege rifle	H. D., No. 3: density, 1.778; gran., 1,258.	7	8	25	1,530	36,000
	H. D., No. 4; density, 1.776; gran., 3,038.	7	......	25	1,578	27,750
		7	......	35	1,411	31,000

With a view to employing a chamber in a rifle of 4.5-inch caliber, some experiments were conducted with cartridges of reduced diameter in the service 4.5-inch rifle, in order to ascertain the effect of an increased air-space in the portion of the bore occupied by the charge.

The powder employed in these experiments was of irregular grain; density, 1.778; granulation, 950.

With this powder, although the charge was gradually increased up to 10 pounds without incurring any excessive pressures, no useful effect was obtained beyond 8 pounds, owing probably to the great length of the cartridge. With that charge and a 25-pound projectile the velocity was 1,528 feet; the pressure, 27,000 pounds.

POWDERS FOR THE 3-INCH AND 3.5-INCH FIELD RIFLES.

The powders procured for trial with these guns were obtained from the Messrs. Du Pont. They were of irregular granulation, and differed from each other chiefly in regard to size of grain. No very satisfactory results have so far been obtained with the 3.5-inch rifle, but excellent results have been obtained from the 3-inch rifle, as shown by the firing records of the 3-inch breech-loading rifle. (See Report of the Ordnance Board on the trial of this gun.) A mean of four rounds with the maximum charge employed is as follows:

Nature of gun.	Kind of powder.	Weight of charge.	Weight of projectile.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
3-inch breech-loading rifle	I. A., density, 1.75; gran., 2,200..	3	10.5	1,542	36,333

The size of the grains of the above powder is shown on the plate, (Fig. 1.)

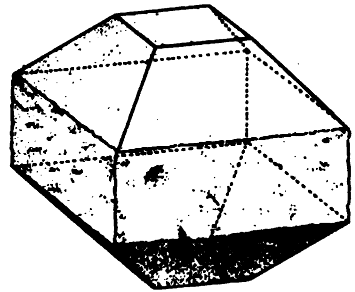
The experiments with powders are yet in progress; and from the success already obtained, it is hoped that they will soon be so far completed as to have secured for the different calibers, if not the most satisfactory powders, at least powders which shall possess a great superiority over those in present use, as regards velocities and pressures.

EXP

Fig. 1.

Fig. 6.

Fig. 9.



Appendix H.[2]—Report of Chief of Ordnance, 1879

REPORTS OF THE ORDNANCE BOARD.

LIEUT. COLS. S. CRISPIN AND T. G. BAYLOR, ORDNANCE DEPARTMENT
CAPT. F. H. PHIPPS, RECORDER.

APPENDIX I.

GUNPOWDER.

(Thirteen plates.)

TABLE OF CONTENTS.

NOTE.—Compiled from "Ordnance Notes"; "Ordnance Report" 1877; "Ordnance Manual" 1861; English "Hand-Book on the Manufacture of Powder"; Benton's "Ordnance and Gunnery"; Cooke—"Naval Ordnance and Gunnery"; Marvin—Granulation of Powder"; and Marvin—"Object and Resources of the Naval Experimental Battery at Annapolis."

LIST OF PLATES.

GUNPOWDER.

Gunpowder is the agent employed in modern warfare to propel projectiles from all guns and small-arms, and generally as the bursting-charge of projectiles; for the explosion of mines; blasting purposes, &c., It is a mechanical mixture giving light, heat, and gas in the combustion or chemical union of its ingredients.

Explosion is a phenomenon arising from the sudden enlargement of the volume of a body; as in the case of gunpowder, the solid body is rapidly converted into a gas many times its volume. If the body is confined in a limited space and exploded, great heat is developed and a vast expansion or propelling force produced, the volume of gas being many times greater than that of the powder.

In the United States service, gunpowder is obtained from private manufacturers. It is distinguished by granulation, irregular, as *musket*, *mortar*, *cannon* and *mammoth*; regular, as *cubical*, and the *molded powders*, *i. e.*, *pellet*, *hexagonal*, and *prismatic* (perforated hexagonal prisms). In all of these, the proportion of the ingredients are the same; they differ only in the size and shape of grain, density and details of manufacture.

Musket powder is used for small-arms; mortar for field-guns; cannon for light siege-guns, and the larger-grained and special powders for heavy sea-coast guns.

NOTE.—Special powders are now being experimented with for both field and siege guns.

MATERIALS.

The materials required are *potassium nitrate (niter)*, *charcoal* and *sulphur*. They should be of the greatest possible purity to insure excellence of quality, and guard against accidents in manufacture. The proportions by weight of the ingredients used in the United States service powder are, $\left\{\begin{smallmatrix}75\\76\end{smallmatrix}\right.$ nitre; $\left\{\begin{smallmatrix}15\\14\end{smallmatrix}\right.$ charcoal; 10 sulphur.

It is essential to the successful and uniform manufacture of powder that the ingredients should be procured in their rough state, and be refined and prepared for use at the factory; this is also necessary as a security against accidents at the mills. All foreign matter must be carefully excluded, and every precaution taken against their introduction in handling and moving the refined materials.

SALTPETER.

Saltpeter (*niter, potassium nitrate*) is composed of 53.45 nitric acid, and 46.55 of potassa; crystallizes in transparent, colorless, six-sided prisms; has a cooling, saline, and slightly bitter taste; deflagrates violently on burning coals; inodorous and anhydrous, not deliquescent in common air, but is so in an atmosphere saturated with moisture. It melts at about 662° into an oily-looking liquid, and may be cast into molds; decomposes at 716°; is soluble in cold, but more so in hot water, the solubility increasing with the temperature.

100 parts of water at 32° dissolves 13.32 of niter.
100 parts of water at 64.4° dissolves 29.00 of niter.
100 parts of water at 113° dissolves 74.00 of niter.
100 parts of water at 212° dissolves 246.15 of niter.

Hence, on cooling, a hot saturated solution deposits the greater part of the salt dissolved.

Saltpeter occurs naturally in great quantities, as an efflorescence on the surface of the earth, in many of the warm countries, particularly in

India, where there is sufficient to supply the wants of the whole world. It also occurs as a saline crust in caverns in some parts of the globe; and in the vicinity of Monclova, Mexico, it is found in great purity in veins or mines.

It exists in certain plants, and is formed spontaneously by the decomposition of animal and vegetable substances when mixed with substances containing potash and kept at an even temperature in moist situations. On this principle artificial niter-beds are made, from which large quantities of niter are obtained, in France, Germany, Sweden, Hungary, &c. Saltpeter obtained from any of these sources may be separated from the greater part of the foreign salts and earthy matter by lixiviation with wood-ashes and evaporation. The nitrous earth of India yields about one-fifth of its weight of niter; that of the niter-caves, from one to ten pounds of niter to the bushel. The best artificial niter-beds afford annually about a quarter of a pound of niter to a bushel of earth. Most of the saltpeter used in the United States for the manufacture of gunpowder is obtained from India, whence it is imported in a crystallized state called *crude saltpeter*, containing generally from 15 to 18 per cent. of foreign salts, earths, and water.

TEST OF CRUDE SALTPETER.

The process of testing now used in this country, as well as in England and India, is that of analysis. The chlorides that the crude saltpeter contains are precipitated in the form of the chloride of silver by adding the nitrate of silver to the solution of a given weight of the sample to be tested. The sulphates are precipitated in the form of the sulphate of baryta by adding the nitrate of baryta to the solution of a given weight of the sample; the amount of these impurities can now be calculated.

MANUFACTURE OF GUNPOWDER.

Refining saltpeter is for the purpose of removing the impurities and all earthy matters which may be present, and is effected by boiling and skimming the grough or crude saltpeter in large open boilers, and afterward drawing off the liquor and filtering it through canvas bags. The *modus operandi* is as follows: About 40 cwts. of saltpeter in its crude state is put into an open copper boiler capable of containing 500 gallons; about 270 gallons of water is added to this, or about .66 of water to 1 of saltpeter; these are allowed to stand all night; in the morning a fire is lighted under the boiler, and in about two hours afterward they will have reached a temperature of 300° Fahr. and will be boiling freely.

During ebullition by constant stirring, the light matter, containing many impurities, rises to the surface, and is skimmed off (a little dissolved glue will facilitate the operation). When the skum ceases to rise, cold water is freely dashed on the surface of the boiling liquid to precipitate the chlorides that would otherwise be retained on its surface. After boiling until the solution of the nitrous salts is effected, the fire is allowed to go out; when all ebullition has ceased, the foreign salts and chlorides being the heaviest, are precipitated. The boiler is provided with a false bottom perforated with holes, through which these impurities pass and fall to the bottom of the boiler.

In about an hour after the fire has been extinguished, the temperature of the solution falls to about 220° Fahr. A siphon is introduced, the end of which is kept about 1 inch from the false bottom of the boiler,

so as not to disturb the sediment. The liquor is drawn off by the siphon into a trough, the bottom of which is fitted with four or five gun-metal taps, communicating with suspended Dowlas canvas filtering-bags, of the shape of an inverted cone. If crystals form on the filtering-bags, hot water is poured over them to keep the canvas open, a constant supply for the purpose being obtained from a vessel provided with a flexible pipe, having a finely-pierced rose-head placed in close proximity to the filtering-trough. When all the liquor has passed through the filtering-bags, it is run to a cooler about 12 feet long by 6 feet wide by 1 foot deep, lined with sheet copper, and placed by the side of a washing-vat.

The liquor in the cooler is stirred by a wooden rake until the temperature is reduced to about 180° Fahr., at which temperature the mother-water separates from the saltpeter held in solution; when it falls below 180° a large number of very minute crystals are formed, which are collected and thrown on to a wire-cloth drainer, fixed at an angle immediately above the cooler, that the strainings may run back again into the cooler; the saltpeter, when sufficiently drained, is raked into the washing vat—also furnished with a false bottom of fine copper-wire cloth.

The whole charge receives three washings; in the first and second, pure water is freely sprinkled over the saltpeter from a rose, and after standing about fifteen minutes the liquor—being very rich in mother-water and saltpeter—is run off into crystallizing pans by a tap at the bottom of the washing-vat. In the third washing the vat is entirely filled with cold water, and the liquor, after standing for about half an hour, is drawn off; it now only contains a small quantity of saltpeter, and is not run into the crystallizing-pans, but collected in an underground tank for future use.

The saltpetre obtained by the above process is an almost perfectly pure white salt. It is placed in stone bins perforated with small holes in the ends and sides, where it is allowed to drain. The saltpeter contains from 7 to 12 per cent. of water, but during the time it remains in the bins about 6 or 7 per cent. is drained off. It is now fit for making gunpowder if used immediately; but if required for storage or transport, it is better to evaporate the remaining water, which is done by drying in a hot chamber in the following manner:

The saltpeter is spread out about 2 inches thick on shallow trays of sheet copper, and placed on racks in a hot chamber heated to about 260° Fahr., by a flue under the floor. The saltpeter is stirred once or twice; from four to six hours is sufficient to evaporate the remaining moisture. It is taken out and emptied into shallow trays, allowed to cool, and then put into barrels and stored.

By the above process about three-fourths of the saltpeter is crystallized, the remaining portion being held in solution by the mother-water that remains. When this has cooled to within 7° or 8° of the temperature of the atmosphere, large crystals are formed, adhering to the sides and bottom of the cooler, and are collected and put with the grough into the next charge of the boiler; the mother-liquor is collected and pumped into a boiler and evaporated to a fourth of its original quantity, and drawn off by a siphon, passed through filtering-bags, and collected in a receiver, whence it is run into copper pans of thirty-six gallons each and crystallized. The crystals obtained in this manner are pure, but contain cavities of mother-water; it is found best to use them in the next charge as grough.

Over the sediment in the bottom of the evaporating-pan hot water is poured, the whole well stirred to extract any saltpeter that may remain;

after settling, the solution is drawn off and passed through the filtering-bags previous to being run into the crystallizing-pans. Should the filtering-bags become clogged by impurities they are removed and placed in larger bags in a cleaning apparatus, where, together with the bags in which the saltpeter is imported, they are well washed in hot water; this water, containing a small percentage of niter, is also collected in the mother-liquor tank. The bag-cleanser is also used for washing the skimmings and foreign salts, &c.; the residue with the refuse from the evaporating-pans is sold for manure.

The water from the various washings and drainings is conveyed to the underground tank, pumped into the copper boiler, and is used instead of pure water in the next charge; as it contains a small percentage of saltpeter, a less quantity of grough is required.

Tests.—A solution is tested with litmus for presence of an acid or alkali; with a solution of nitrate of silver for chlorides; with a solution of chloride of baryum for sulphates; with oxalate of ammonia for lime. In ordinary test the second is the only one used, and for chloride of sodium.

Sulphur.—Sulphur is never found pure, but mixed with earths, and often with various salts. It is found in the vicinity of volcanoes, large quantities being imported from Sicily; it is often found with metallic ores, as copper, iron, &c.

Sulphur is unfit for use in a crude state; it requires to be refined. This is done by subliming and distilling.

By melting, all earthy matters are left at the bottom of the retort in which the melting is done, the pure sulphur, as vapor, passes upward, and is sublimed and distilled by condensation at two distinct periods of its temperature.

A thick, large, round cast-iron melting-pot or retort is used, built in brick-work with a furnace below. The retort has a movable lid, the joint being made air-tight by clay; the lid is sufficiently large to admit a man for cleaning out the pot. In the lid is fitted a 4-inch plug, tapered for the purpose of charging the retort. Near the top of the retort two pipes branch at right angles, each fitted with a sluice-valve at the end nearest the retort; one of these, the subliming-pipe, from 12″ to 14″ in diameter, rising at an elevation of 35°, is used to conduct the vapor from the retort to the subliming-chamber situated at a distance of about 15 feet from the retort. The chamber is 12 feet in height by 10 feet in diameter at the base, dome-shaped, lined with flag-stones, the floor covered with sheet-lead. Near the bottom are two doors, the inner of iron, the outer of wood, air-tight, and lined with sheet-lead. Through the bottom of these doors is a small tube leading to a cistern of water, which takes up the sulphuric acid. The outer pipe, from 7 to 8 inches in diameter and 8 feet long, is used in conveying off the vapor at a higher temperature than required for subliming; this inclines downward at an angle of 20° delivering the vapor to a receiving-tank inclosed in an outer jacket; cold water from a cistern circulates through them, through the annular space about 1.05 inches in width. The water enters the jackets at their lowest points, and passes off at their highest, near the retort.

The receiving-tank fitted with a movable lid somewhat similarly arranged to that of the retort, has a plugged hole in the center, through which a rod is introduced for gauging its contents. A small pipe fitted to the top of this tank conducts any non-condensed vapor to a chamber where the "flowers" are precipitated. This chamber is occasionally cleaned out by a small door. A discharge-valve is fixed to the bottom of the receiving-tank for drawing off the sulphur into molds.

About 6½ cwts. of crude sulphur are put into the retort, the sluice-valve on the subliming-pipe and the plug in the retort-lid left open, the sluice-valve on the distilling-pipe closed, a slow fire applied under the retort; in two or three hours the raw material is melted down.

At 170° Fahr., evaporation commences; at about 200° Fahr., melting begins; 239° Fahr., the sulphur is perfectly fluid; and at 560° Fahr., it is ready for distillation. So soon as the melting begins, a pale yellow vapor arises; the plug is inserted in the lid of the retort, the vapor passes to the dome of the subliming-chamber near the top, and falls in a shower of very fine condensed particles termed "flowers of sulphur."

After two or three hours, as the heat increases, the vapor in the retort becomes a deep reddish-brown color, when the sluice-valve on the subliming-pipe is closed, and that on the pipe leading to the distilling-tank opened, the cold water constantly circulating through the jacket of this pipe and also of the receiving-tank keeps them cool, the vapor rises from the retort and passes along the pipe, becomes condensed, and runs into the tank below, a thick yellow fluid. When nearly all is distilled (which is ascertained by gauging the depth of the liquid sulphur in the tank), the sluice-valve on the distilling-pipe is shut, the fluid in the receiving-tank allowed to cool for an hour or two, when it is run off by the valve to molds, and allowed to cool and solidify. These molds are used wet, otherwise the sulphur will adhere on solidifying. When cold, the refined sulphur, broken into lumps, is ready for use. The vapor remaining in the retorts passes into the dome of the subliming-chamber, where it is evaporated as "flowers." The earthy matter in the retort is afterward cleaned out.

The "flowers" of sulphur are unfit for making gunpowder, on account of the acid they contain, unless required for fireworks or composition. They are returned to the melting-pot with a fresh charge. The crystalline, or distilled sulphur, only is used in making gunpowder.

To test sulphur, burn a small quantity on white porcelain; if fit for the manufacture of gunpowder, there should be not more than 0.25 per cent. of residue, or, dissolved in boiling distilled water, blue litmus paper should but slightly redden.

Charcoal.—Charcoal, the residue after wood has been charred, as an ingredient of gunpowder, is next in importance to saltpeter. When uniformity in quality of gunpowder is required, great care must be exercised in its preparation, for the chemical composition of charcoal—*i. e.*, the percentage of carbon contained therein—will affect the quality of the gunpowder to a considerable degree; therefore, extreme care has to be exercised in charring the wood. Gunpowder should contain no less than 15 per cent. of charcoal.

Much depends upon the quality and condition of the wood employed; the sap should be thoroughly dried in the wood to secure the best quality of charcoal; this end is attained by desiccating newly-cut timber in a hot chamber for ten or twelve days, although it is questionable if the charcoal so obtained is as good as that produced from wood that has been seasoned for a number of years. Small wood, perfectly clean, free from bark, quite dry, are essential requisites for making good charcoal.

The kind of wood commonly used is that of the willow species—the common white Dutch willow, the poplar, and the alder are generally preferred; other woods are, however, frequently used, and for a first-class strong powder, black dogwood is said to be best, but its great cost prevents its being largely adopted.

Distilling the wood in retorts is the method usually employed for procuring a light and equal quality of charcoal; pit-burned charcoal is, how-

ever, preferred for fuse, pyrotechnic compositions, &c., on account of certain qualities it possesses. The method of distilling in retorts is as follows: A number of retorts set in brickwork at a suitable height from the ground floor, under which a furnace is provided; the bottoms of the retorts are protected from the direct and intense heat of the furnace by a fire-brick lining, through openings in which, and by flues, the flame passes round the retorts before reaching the chimney. The wood must be small, of eight or nine years' growth; it is obtained early in the fall, its bark entirely removed, cut into lengths of about 3 inches and stacked for drying. When thoroughly dried it is put into a sheet-iron cylinder or "skip," having a movable lid or door at one end, which is placed horizontally on an iron carriage corresponding in height with the door of the retort; the carriage is run forward to the mouth of the retort, the cylinder containing the wood slid into the retort, fitted with an air-tight door, having been previously heated to a dull red heat.

The process of charring commences, the steam, tar, and gas in the wood pass from the cylinder by holes in the door, through a pipe to the furnace and are consumed. From three to four hours are required to completely char a cylinder of wood. The cylinder with its contents is drawn out of the retort by a block and tackle, lowered into an air-tight cooler with a close-fitting lid, and allowed to remain for about half a day; it is then placed in a smaller cooler where it remains until cold. After the charcoal has been carefully picked, it is fit for use in making gunpowder. About three charges can be burned in each retort every twelve hours.

A good and uniformly pure charcoal has, if properly made, a jet black appearance, the fractures show a velvet-like surface, and appear the same in both large and small pieces. It should not scratch soft polished metal, and if treated with distilled water there should be no appearance of alkali.

From 20 to 25 per cent. of charcoal is obtained from willow and alder, and from 25 to 30 per cent. from black dogwood; the latter is very dense, tough, and of slow growth, its usual size being about one inch in thickness. When charred, it has a yellowish looking surface, and is slightly metallic in appearance.

The kind of wood from which the charcoal has been made is known by the pith; that of dogwood is circular and large for the size of the wood; that of the willow is also circular, but somewhat smaller; that of alder forms a figure of three equidistant radial lines.

Charcoal is very porous, and quickly absorbs moisture; therefore a great store is never kept. Previous to use, it is very carefully examined and picked, uncharred pieces being excluded.

To test charcoal for an alkali, finely powder a small quantity and boil it in distilled water, filter and test with litmus paper reddened by weak acid. Should the charcoal contain alkali, the paper will be partially or wholly restored to its color.

Pit-burned charcoal is used in the manufacture of "pit gunpowder," and is suitable for filling fuses, port-fires, &c.; it is also used for pyrotechnic compositions, and such purposes.

MACHINES USED IN MANUFACTURE OF GUNPOWDER.

CHARCOAL-GRINDING MILL.

Before the ingredients are mixed together, they must be pulverized or ground to a fine powder. Charcoal after standing a fortnight is ground

in an apparatus somewhat similar to a coffee-mill on a large scale. The mill (Plate 1. Fig 1.) consists of a cone secured on a vertical spindle provided with teeth running spirally over its entire outer surface; the cone revolves in a cylinder provided with teeth on its inner surface; these teeth are spiral also, but incline in the opposite direction to those on the cone.

The revolving cone is adjustable in a vertical direction to increase or diminish the space between its teeth and those of the fixed cylinder; thus a coarse or fine charcoal is produced at will. The adjustment is effected by means of two hand-wheels working on a fine screw-thread cut upon the small vertical cone spindle, which spindle can be moved upward or downward by means of the hand-wheels through the large hollow shaft upon which the bevel driving-wheel is keyed. Motion is communicated from this shaft to the small one by means of a feather upon the surface of the latter, which fits and works in a groove cut in the inside of the hollow shaft. The small hand-wheel is used for locking and securing the larger one in any required position.

The hopper above receives the charcoal. On the under side of the cone, and revolving with it, are a couple of arms, that carry the ground charcoal to the discharge spout on one side of the fixed cylinder and conduct it to a sifting reel; this reel is simply a skeleton cylinder of wood, covered with copper wire cloth, having fine meshes thirty-two to the inch.

The sifting reel is driven by a pair of bevel wheels set at a slight angle to allow the charcoal to run readily along the interior; as it revolves, it causes the particles of charcoal to be continually rolling over each other and covering new surfaces of the reel; the fine particles pass through the meshes of the wire cloth and fall into a receiving bin, whilst the larger ones are thrown out at the lower end of the reel to another bin, whence they are taken and returned to the hopper. The reel and bins are inclosed entirely in a wooden framework and covering, so as to prevent the dust, which is very light, from spreading over the house. Doors are provided in this wooden covering, by means of which the ground charcoal can be removed.

After being ground the charcoal stands for about eight or ten days before using it; owing to the readiness with which it absorbs oxgyen when in the pulverized state, it is apt to become heated, and spontaneous combustion to ensue. The danger from this cause is much lessened when t is st ored in small quantities and in separate iron cylinders or bins.

SALTPETER AND SULPHUR GRINDING APPARATUS.

The saltpeter, if used immediately after being purified, is so fine as to require no further reduction of its particles before mixing; but if it has been dried for storage it must, like the sulphur, be reduced to a very fine powder. They are ground separately in a small machine somowhat similar to a mortar-mill. The machine (Plate I, Fig. 2) consists of a pair of edge rollers traveling round a strong circular cast-iron bed, revolving at the same time on their own axes.

The speed of these rollers is eight revolutions per minute round the bed; they are each 4 feet in diameter, and weigh 30 cwt. Each one travels on a different path, one being near to the inside curb, or "cheese," as it is technically called, whilst the other is farther away from the center. A shaft or spindle common to both passes through their centers, and between them is a cross-head fixed on a vertical shaft driven by means of bevel gearing, the pinion being secured on the main horizontal driv-

ing shaft underneath the machine, whilst the vertical shaft, upon which the large bevel wheel is fixed, passes through the cross-head; this latter being provided with suitable brass bushes, in order to allow the rollers to rise or fall according to the thickness of the material under them.

The material to be ground, whether saltpeter or sulphur, is spread evenly over the bed of the machine to a thickness of about 1.05 or 2 inches; the rollers are then set in motion. A very short time suffices to complete the operation. The material, when ground, is shoveled from the bed into tubs and emptied into a hopper placed above a sifting reel (Plate I, Fig. 3), which is similar in all respects to the charcoal reel. As the reel revolves, certain projections provided on the shaft strike against similar projections on the bottom of the trough that conveys the material from the hopper to the reel, and as this trough is slung under the hopper it is made to vibrate and cause the material to be shaken gradually from the hopper to the reel. The fine particles pass through a wire cloth of thirty-two meshes to the inch and fall into a bin provided; the coarse particles are thrown out at the end into another bin, whence they are taken and reground.

The ingredients are weighed out very accurately, in the proportions of 75 of saltpeter to 15 of charcoal and 10 of sulphur. About 50 pounds of this mixture, constituting a charge for the incorporating mill, is placed separately in small bags and taken to the mixing machine.

THE MIXING MACHINE.

This machine (Plate II, Fig. 4), consisting of a hollow drum of copper about 2 feet wide by 3 feet in diameter, revolves at a speed of thirty-five revolutions per minute. The bearings of this drum are hollow; a shaft passes through them, having in the interior of the drum an eight-sided boss or tube secured to it; into this a series of arms or flyers are screwed, there being five on one face of the octagon and six on the next, alternately. They are made of a flat section, forked at the ends, provided with holes through their flat sides; each one is set at a different angle to the next; their points just clear the inside of the drum, and they revolve in the opposite direction to it at the rate of seventy revolutions per minute.

The three bags of ingredients (50 pounds in all) are emptied one at a time through a door into the copper drum; five minutes' work will be found to thoroughly mix them.

The door in the drum is opened, the composition falls down a chute into a tub; after being spread out it is carefully examined, and then placed in the receiving bags. The bags are tightly tied up, it being very essential that this operation be carefully performed; for, should the composition be allowed to remain loose in the bags (the ingredients having very different specific gravities), the saltpeter would fall to the bottom, the charcoal rise to the top, and the sulphur occupy the center. The bags are put into small magazines, separate from all buildings containing machinery, laid on their sides, so that the weight of the saltpeter may affect the mixture as little as possible. The composition is now ready for

THE INCORPORATING MILL.

The incorporation of the ingredients that form gunpowder is by far the most important process in the whole manufacture, for unless the minute particles of the ingredients be thoroughly mixed, all subsequent operations, however well performed, will not compensate for the error

The incorporating mill, which is shown by Plate II, Fig. 5, consists of two large and heavy "hard-chill" cast-iron-edge runners, revolving on a circular cast-iron bed; the peculiar action of these runners is well adapted for thoroughly grinding and incorporating the several ingredients; their great weight is for crushing the ingredients, which are also ground together by the twisting action produced by the rollers traveling round in so small a circle. Each roller travels over the bed in a separate track, and is assisted by a plow (hereafter described), which mixes the material so that it is subjected to crushing, grinding, and mixing by one operation.

Incorporating mills in a gunpowder factory are usually grouped, and the motive power may be water or steam; in either case the power should be capable of driving four or more pairs of runners. Each pair is so arranged that it can be disengaged or put in gear at pleasure by means of a friction-clutch, without interfering with the steady working of the engine or water-wheel. When the latter is employed, its speed is regulated by a governor in connection with the sluice; by this means the flow of water is caused to immediately increase or diminish as a pair of runners is put in motion or stopped, and thus a regular speed always maintained.

The runners travel round the bed at the rate of eight revolutions per minute; they are 6 feet 6 inches in diameter by 15 inches broad on the face, and weigh four tons each. As already stated, the two travel on different paths, the one being near to the outside rim or curb of the bed, while the other travels near to the inside curb or "cheese." A horizontal shaft or spindle, common to both runners, passes through their centers, and between them is a cross-head fixed on a vertical shaft driven by means of a bevel wheel and pinion, the latter being secured on the main driving shaft that passes underneath the bed of each mill, and common to all.

The vertical shaft passes through the cross-head, and is provided with brass bushes, which allow the runners to rise or fall according to the irregularity in the thickness of the material under them. On each side of the cross-head, and projecting outwards, is an iron bracket having a plow (made of a wedge-shaped piece of wood shod with felt and leather) fitted to it, so arranged as to sweep the bed and keep the composition under the runners. One plow sweeps against the outside curb immediately in front of the runner that travels round the larger circle; the other against the "cheese" or inside curb immediately in front of the runner that travels round the smaller circle. The inside of the outer curb, as well as the outside of the cheese where the plows work and rub against them, are covered with copper or gun-metal.

The composition attains a body in about one hour after the runners are set in motion, the action of the plows in moving the whole of the material on and across the bed thoroughly mixes it, and subjects every particle to the same amount of pressure.

Each pair of runners is provided with a tell-tale dial, which shows the time the mill has to run and the condition of the cake from time to time. From three to four hours is the period a charge should be on the mill, providing the engine or water-wheel is maintained at its proper speed. This timing of the charge is a very important point in the manufacture, where powder of an equal quality is required; the attendant must watch for any change in the atmosphere, so that he may work the charge dry or moist, according to the humidity of the air.

The charge coming from the mixing machine is spread equally over the bed of the mill, and moistened with from four to eight pints of dis-

tilled water by a fine rose-ended watering pot, the quantity being regulated according to the state of the atmosphere.

The cake should be of a blackish-gray color when broken, of a uniform appearance without any white or yellow specks, the presence of which would indicate insufficient incorporation. It should not exceed half an inch in thickness, in order to be thoroughly incorporated, nor be less than a quarter of an inch thick, to insure safety; if the runners are allowed to come in contact with the bed, the friction caused by their twisting action is so great that an explosion would almost certainly result.

At the expiration of three or four hours the charge will have attained all the properties of gunpowder; the powder will not be improved by heavier runners or an increase of speed. For fine sporting gunpowder, however, the operation of incorporating is continued in some cases for eight hours and with heavier rollers. It is doubtful whether the powder is much improved thereby; the purity of the ingredients is of more consequence; on this the quality of the powder depends much more than upon a long or short period of incorporation, for if regularity be observed and the runners are of one size and weight, and the charges are worked for an equal length of time and under the same conditions, a fairly uniform powder will result.

A method for testing whether the incorporation has been well performed is to take half an ounce of the cake granulated by hand and flash it on a glass plate; a slight residue only should be left on its surface.

As the incorporating mills are generally in groups, it is necessary to prevent explosions spreading amongst the mills. This is very effectually done by the use of a drenching apparatus which consists of a large board, acting as a flapper, placed horizontally over each pair of runners. This flapper is attached to a shaft running throughout the entire group of mills, and in connection with it, and immediately over each set of runners, is a copper cistern holding about 40 gallons of water, so arranged and poised that when the flapper is raised by an explosion the catch is disengaged and the cistern, overbalancing, empties its contents upon the mill. This does not prevent damage to the mill in which the explosion first occurs but confines the damage to it. In addition, an arrangement is provided whereby the attendant can, in case of an explosion in any part of the works or in his immediate neighborhood, upset the cisterns of water from the outside and thus prevent the explosion spreading.

In a well-constructed incorporating mill all movable parts, such as bolts, nuts, &c., are fitted with the greatest care, and at each end of the runner shaft, and also over and under the cross-head between the runners, large gun-metal discs or drip-pans are fitted; these not only prevent any oil or greasy matter dropping into the charge, but likewise any bolt, nut, or pin that may have become loose in the vicinity of these parts and possibly producing an explosion.

Where steam is employed as the motive power, care must be taken at all times to prevent sparks being emitted from the boiler chimney; this may be effected in several ways, either by using anthracite coal or coal and coke for the boiler furnace, or by having a spark catcher or arrester fitted inside the flue at the base of the chimney, or a number of baffle-plates placed in the chimney itself in a zigzag manner. If proper precautions are taken, and the flues are regularly cleaned out, there will be no risk whatever in using steam-power.

THE BREAKING-DOWN MACHINE.

The powder after incorporation is taken from the mills in open tubs and placed in small magazines, where it is allowed to remain for a day, to give the viewer time to examine the quality of the cake, and to compare the production of one mill with that of another, for it is found that that part of the charge which has been subjected to the last few revolutions of the runners is generally a little drier than the rest; therefore, allowing the whole to remain exposed for a short time tends to equalize the moisture, two or three per cent. of which greatly assists the operation of pressing.

The incorporated powder, in the condition of soft cake, is broken in pieces of uniform size, so that the spaces between the plates in the press-box (hereafter described) may be equally filled and the powder subjected to the same amount of pressure over its whole surface. Reducing the mill cake to a uniform size also assists in mixing any portions that may be more dense than others.

The breaking down of mill cake is effected by the breaking-down machine (Plate III, Fig. 6), which consists of gun-metal side frames, supporting two pairs of gun-metal rollers, the one pair being immediately under the other. These rollers are $7\frac{1}{4}$ inches in diameter, and have a total length for operating upon the cake of 2 feet 6 inches. The surfaces of the upper pair have grooves of 1.05-inch pitch, cut longitudinally to a depth of $\frac{1}{8}$ inch. These rollers work at a speed of 25 revolutions per minute, and motion is imparted to them by means of a main driving shaft and spur gearing connected with the motive power. The back roller of each pair works in a sliding bearing, and is pressed forward to its opposite roller and kept up to its work by means of weighted levers. This is a safety arrangement, and is provided in order to admit of the rollers opening to allow any large quantity of the cake, a hard lump, or any foreign substance, to pass freely through them, thus preventing injury to the machinery, and possibly an explosion. There is also a scraper attached to each pair of rollers for removing from them any powder adhering to their surfaces.

To prevent the dust spreading about the building, the rollers are inclosed in sheet-copper and gun-metal casings, which act as spouts and guide the meal into boxes placed underneath the machine.

The working of the machine is as follows: The incorporated "mill-cake" brought from the magazines is placed in a wooden hopper holding about 700 pounds. Under the open side of this hopper works an endless band of strong canvas, having strips of leather stitched across it at 4 inches apart. This band presses over two drums, the upper one being driven from the gearing, so that when in operation this band revolves and carries a portion of the "mill-cake" with it from the hopper and discharges it over the upper drum between the first and uppermost pair of rollers. After being crushed and passing through these, it falls into the second pair immediately underneath, where it is further broken up into pieces of the required size. From these it falls into the spout, and is conveyed to the boxes placed underneath.

When the hopper has been filled with "mill-cake" the attendant retires to a place of safety, and then starts the machine. After working for about half an hour, which is sufficient to break down a charge of 700 pounds, he stops the machine, and after waiting a few minutes enters the house, empties the boxes, and removes the powder before refilling the hopper.

The meal, as taken from the boxes, is conveyed in tubs and placed in other small magazines, from whence it is taken to the press-house.

All these dangerous operations are carried on in separate buildings, well removed from each other; as a matter of precaution the machine is entirely constructed of gun-metal and wood, except the shafts, which are of wrought iron incased in copper.

THE HYDRAULIC PRESSING APPARATUS.

The last operation and that of pressing the meal into a solid cake is for the purpose of fitting it to be made into a hard grain of equal density. The powder is brought from the small magazines to the press-house, where it is compressed into hard cake. Many advantages are gained by this operation. First, the cake when made into grain of the required size absorbs less moisture from the atmosphere, the lasting qualities of the powder are much increased, especially if glazed; again, by having been compressed the powder is less liable to be reduced to dust in transport. By a closer connection of the ingredients a larger volume of gas is produced, bulk for bulk, than from a soft light powder; it also produces more grain than could be obtained from "mill-cake" not pressed; there is less waste by dust, and in addition to this a hard clean grained powder does not foul the gun so much as a soft powder.

For compressing the meal powder into "press-cake" a powerful hydraulic press (Plate III, Fig. 7) is employed. The apparatus for holding the meal consists of a very strong gun-metal box incased on the outer and inner sides with oak; it is 2 feet square, and 2 feet 6 inches deep; the bottom and one side are permanently fixed to each other, but the other sides are hinged to the bottom to allow of their being opened; when shut, these sides are firmly held together by strong coarse-threaded metal screws.

The box, when about to be filled, is laid on its side in front of the press, and the uppermost side is opened and laid back. Two guide racks of gun-metal, with wooden ribs on them, forming a number of grooves one-tenth of an inch in width and five-eighths of an inch apart, are hung on the inside of the box to those sides that have not been opened; into these grooves a series of gun-metal plates one-tenth of an inch thick are slid. The spaces between the plates are filled with the meal powder, the racks are withdrawn, leaving the plates supported in their position by the powder between them. The third side, which has remained open, is then lowered down and screwed fast up to the two sides already in position. The box is provided with two projecting gun-metal claws that fit into a mandrel attached to the front of the press; upon this mandrel the box is now turned by means of overhead tackle, the mandrel being so adjusted that when the box is raised partly into a vertical position it is pushed over and lowered down exactly on the center of the press table. Attached to the press cross-head are two overhead rails, carrying a large block of hard wood, which is hung and travels upon these rails by four wheels; when the box is turned over on its side for the purpose of filling, this block is drawn back to the extremity of the rails, and when the box is filled and replaced on the table and in the proper position for pressing, the block is drawn forward until it arrives exactly over the center of the box, where it is retained by a catch.

The press is now put in motion by means of pumps, driven by steam, water, or hand power in separate buildings, on the opposite side of a high traverse that divides one from the other. In the pump-house the attendants remain in safety while the pressing is being done.

The pumps of the description generally used are fitted with large and small plungers. At first, when the material to be pressed is soft, the large plungers are used and the box raised rapidly; but when the press has traversed about three-fourths of its distance the smaller ones are worked until such time as the powder is subjected to a pressure of 70 tons per square foot.

When the pumps are first put in motion one of the attendants remains in the press-house for a short time to see that the block enters the box fairly, and that it is in the center; a clearance of about a quarter of an inch is allowed all round between it and the box. If all is in order, the attendant retires to the pump-house when the requisite pressure has been obtained; the press is allowed to stand for a few minutes to allow the air to escape and the powder to consolidate. Should the pressure go down from this cause, the pumps are again set in motion until the full pressure is attained; after allowing a few minutes to elapse, the escape-valve is opened and the ram with the box descends. The overhead block is now run back out of the way, the box turned over on its side, all the fixing screws removed, the uppermost side is lifted up and turned over, and the other two are opened out. The powder, with the gun-metal plates, will be found standing like a solid mass on the side of the box underneath.

The plates and powder cakes are separated by copper chisels, the cake—being from three-eighths of an inch to one-half inch thick, like slabs of slate—is broken into pieces about the size of a man's hand, by wooden mallets; is collected, put into tubs, and removed to the next magazine and allowed to remain for two or three days; this renders it so hard that it is not easy to break it.

Some difficulty is experienced in obtaining precisely the same density in the pressed powder; any great difference in this particular causes the powder to vary considerably in quality and strength; in fact, until the greatest precision and certainty are obtained, first, in purifying the ingredients, and, secondly, by an equally precise amount of incorporating and pressing, uniformity in the quality and strength of the powder manufactured cannot be secured.

THE GRANULATING MACHINE.

The machine used for granulating the pressed cake is somewhat similar in construction to the breaking-down machine; it is fitted with four pairs of cutting rollers, and rectangular screens below the three upper pairs; these screens convey any grain not properly reduced by the one set of rollers to the next under them.

The machine (Plate IV, Fig. 8) is composed of two side frames of gun-metal, which carry the rollers, screens, and other moving parts. The rollers are placed in pairs at an inclination of about 33°, and have a vertical height of 2 feet 5 inches between each pair; they are 7 inches in diameter, and make from 25 to 30 revolutions per minute, thus giving a speed of about 48 feet per minute to their toothed surface, the length of which for operating upon the powder is 2 feet 6 inches. The press-cake is fed to the machine by an endless band at the rate of about 30 pounds per minute. The teeth in the several pairs of rollers vary in size and form; those on the upper rollers are diamond-shaped, standing out from the surface of the rollers; these teeth are a quarter of an inch apart and the same in depth, and so arranged that those in the one roller work into the spaces of the other.

The second pair of rollers have smaller teeth, but of the same form as

the upper pair; they are a quarter of an inch apart, but only one-eighth of an inch in depth.

The teeth of the third and fourth pairs are differently shaped; in these they are formed by cutting V-shaped ribs longitudinally along the rollers and rectangular grooves a quarter of an inch apart by one-eighth of an inch in depth around their circumferences. The ribs of the one roller work into the grooves of the other, and *vice versa*, and their top and bottom edges are slightly rounded.

On the side bearings, and behind each roller, there is fixed a scraper, the edge of which is provided with teeth corresponding with the grooves in the rollers, so that as the latter revolve, any powder adhering to them is cleared out.

The back roller of each pair is provided with a sliding bearing and is pressed forward towards the front rollers by weighted levers; this arrangement admits of their opening when necessary, and permits a glut of cake or any other hard material to pass them with safety. This is a very essential point, inasmuch as the process of granulating is one of the most dangerous in the whole manufacture of gunpowder. All the rollers are inclosed in copper covers for confining the dust from the cake, and preventing its spreading over the granulating house.

Three screens, one under each set of rollers, for conveying the broken cake from one pair to the next, are placed at an inclination of about 28°, and consist of copper-wire gauze of eight meshes to the inch; underneath, and embracing, all the rollers are three tiers of light separating screens, contained within a deep frame set at an angle of 32°. The upper screen is of copper-wire gauze of eight meshes to the inch; the second of sixteen meshes to the inch, while the third is a very fine (nearly close) screen, and receives the dust from the upper ones and conveys it into a bag.

The separating-screen frame is slung from the gun-metal framing of the machine by light springs made of lance-wood. The screens themselves are also carried from the frame by the same means, and the whole has a longitudinal movement given to it of 182 vibrations per minute, produced by polygonal wheels on the driving shaft, which press against circular but loose-running wheels attached to the separating-screen frame. The surfaces of these wheels are kept in contact by the weight of the screen.

The process of granulating the press-cake is as follows: The cake, having been broken into pieces, is put into a wooden hopper, which holds 700 pounds; the side of this hopper next the inclined frame is open to a shoot—the hopper—when the machine is at work; moves slowly up this inclined frame, the speed being regulated so as to suit that of an endless feed-band made of canvas, with strips of leather sewn across it.

A rope set in motion by one of the machine shafts in connection with a worm and wheel is used to raise the hopper, the cake in which, falling through the shoot on to the endless band, is carried forward to the uppermost or first pair of rollers. From these it is conducted to each successive pair by the screens, and these having a quick vibrating motion, allow any grain that has been broken small enough to pass through them into the upper long separating screen in the frame underneath. Such grain as is too large to go through any of the screens, called "chucks," is collected and passed through the machine a second time. The grain which passes the upper, or eight-mesh long screen, is used for common powder; that which passes through the sixteen-mesh long screen is suitable for rifle or small-arm powder; and that which passes through into the lower screen is dust. The powder as it falls from the

surface of the different screens is collected in separate boxes placed underneath the machine.

When the hopper has reached the limit of its travel upwards, and all the cake has passed on to the feeding band, which it will do in from twenty-five to thirty minutes after the machine has been set in motion, the hopper acts, by a self-acting arrangement, on a clutch, which throws the rope wheels out of gear, and thus stops the further travel of the hopper, while a counterbalance weight prevents its descent. At the same time that the clutch throws the wheel out of gear, it relieves a catch connected with a wire spring and bell; the latter ringing in the bomb-proof house, where the workmen remain while the machine is in operation, gives notice that the hopper is empty. After allowing about five minutes for the band and machine to become quite empty, the apparatus is stopped, and the attendants leaving their place of safety enter the granulation house and empty the grain from the several boxes into tubs for removal. No one is permitted to enter the granulating house while the machine is working, and, as a further precautionary measure, the attendants or others who have occasion to enter the house at other times wear sewn hide-leather boots.

After all the powder is removed, the hopper is let down to its proper place and refilled with cake, and the machine is again ready for use; the attendants leave the granulating house, from the bomb-proof building set the machine in motion, and remain under cover until the bell again rings, when, after a few minutes, they stop the machine; the starting and the stopping are done in the bomb-proof house.

When fine-grain powder is required, rollers with smaller teeth are used, together with screens of 24 and 32 meshes to the inch; the dust produced by this machine, as well as from all the others, is collected and taken to the incorporating mill, where 50 pounds of it is spread out on the bed; after being well damped it is worked under the edge runners for about one hour; it is then fit to be sent forward to the breaking-down machine, the press, and other subsequent operations. The quantity of dust produced varies considerably according to the condition of the teeth of the granulating rollers; if they are much worn, or become foul, as they are apt to do during damp weather, the quantity of dust will be considerably increased, or, if only fine-grain powder is being made, the percentage of dust will be great.

As in the case of the breaking-down machine, so with the granulating machine, no iron or steel is exposed, and indeed there is very little of either used in its construction, the shafts and bed-plate being the only parts made of these metals; the former, as well as the whole floor of the granulating house, is covered with soft leather-hide, and the shafts are all encased in copper or gun-metal. The side frames, rollers, wheels, bolts, nuts, and all other parts of the machine are made of gun-metal, copper, or wood.

A machine of the size described is capable of granulating from 130 to 140 barrels of gunpowder per day of twelve hours, each barrel to hold 100 pounds.

THE DUSTING REELS.

The large-grain powder from the granulating house is called "foul grain," owing to its containing a large percentage of dust that has been produced under the granulating process, for, although a great deal of it is removed from the powder by means of the lower long sixteen mesh screen attached to the granulating machine, still the powder contains a considerable quantity, and the object of passing it through the dusting

reels is to entirely remove what remains, and at the same time to rub down the rough, uneven surfaces of the grain, and thus prevent its becoming dusty again in course of transport. Dust in powder is very injurious, as it absorbs moisture from the atmosphere very readily, which affects the whole mass.

The dust is removed from large-grain powder by horizontal reels (Plate IV, Fig. 9); these are cylindrical wooden skeletons, supported upon a central shaft by radial arms, the periphery of the cylinder being covered with canvas, having twenty-four meshes per inch. The reel is about 8 feet long by 2 feet 6 inches in diameter; the wooden skeleton is made in halves so that it may be easily removed for recovering. The ends are closed by disks, secured upon the main central shaft, and one end is so constructed that it can be opened or drawn back for the purpose of unloading the reel.

When about to be filled, the reel is turned round until the charging door is directly under the feeding hopper; into this three barrels of foul grain are emptied, and when it has all passed through the hopper, the door of the reel is closed and fastened, the reel is set to work at from 40 to 42 revolutions per minute and kept in motion for about half an hour; at the end of this time it will be found that the whole of the dust will have passed through the meshes of the canvas covering, and will be lying at the bottom of the outer wood-work casing in which the reel is inclosed, in order to prevent the dust spreading over the house.

When a number of reels are used, they are all driven from one main shaft which receives its motion from the water-wheel or steam-engine, and each reel is provided with a separate clutch, so that any one may be stopped or set in motion without affecting the others.

When the reel has run the requisite time it is stopped, and the one end lowered about 10 inches; the disk at the lower end is slackened back sufficiently to allow the powder to run out into barrels, which it will do when the reel is again set in motion; when quite empty, the disk is again screwed tightly up to the end, and the reel raised to its horizontal position ready for refilling. By this operation the dust is not only taken from the powder, but the grain, from being rolled over, has its rough surfaces rubbed off, and in the case of large-grain powder, a sufficient gloss is imparted without its having to be passed through the glazing barrels.

The fine-grain powder used for rifle or small arms has a much larger proportion of dust than the large-grain powder, and is therefore dusted in what is termed a "slope-reel," which consists, as in other reels, of a skeleton frame of wood fixed by radial arms on a central shaft, and lies at an incline of 1⅛-inch per foot; the covering of this frame is of very fine canvas, having forty-four meshes per inch, and the reel in this case has no ends; it is also much smaller than the horizontal reel, being only 20 inches in diameter by 8 feet in length, and is driven at 38 revolutions per minute.

The fine-grain powder, as it leaves the granulating machine, is brought from the magazine and placed in the feeding hopper, to which is fixed a loose spout for guiding the powder to the reel. Attached to the central shaft are three ribs or cams which, as the reel revolves, come in contact with and shake the loose guiding spout, imparting to it 135 vibrations per minute, thereby effectually keeping it clear, the fine-grain powder at this stage being very apt to choke up the hopper and spout.

As the powder passes through the reel when in motion it is collected in a tub at the lower end; from this it is emptied back again into the hopper and passed through the reel a second time; this operation is sometimes performed a third time. The fine-grain thus treated, being

only about one minute in the reel, has had no gloss imparted to it; the glazing is effected by passing it through a glazing barrel before it is ready for the drying-stove.

THE GLAZING BARREL.

Some manufacturers glaze large-grain powder by using black-lead, about half an ounce to every 100 pounds of powder. The black-lead, with the powder, is put into a glazing barrel; about one hour is found sufficient to polish the grain. Black-lead is also sometimes used with the fine-grain powder; although its use has some advantages, as lessening the formation of dust, and preventing moisture from affecting the powder so readily, still it is an impurity, and should be used sparingly.

Recently plumbago has been used for glazing, and if pure is preferred to black-lead; a little more than half the quantity is sufficient to give a perfect glaze to the powder, and protect it more effectually from the action of moisture.

The apparatus used for glazing fine-grain powder is placed in the same house as the dusting reel. It consists of a wooden barrel supported and attached to a shaft running through its center, and the whole revolves at 40 revolutions per minute. The barrel is generally made of oak, and about 5 feet long by 3 feet 6 inches in diameter at the center.

A set of glazing barrels consists of four, each pair supported on a shaft. These shafts are of wrought iron, covered on the inside of the barrels with wood, and receive their motion by means of bevel gearing direct from a main shaft. The barrels are inclosed in wooden casings with feeding hoppers on the top. Into each hopper 400 pounds of powder is emptied; the barrels are turned with their doors uppermost, to receive the contents of the hoppers. The apparatus is set in motion and runs from five to six hours, a fine gloss being imparted to the powder by the friction of the grains against each other, the sharp angles and corners are rubbed off, and the powder improved for storage or for transport.

Each pair of barrels can be stopped or put in motion at pleasure, by throwing a clutch in or out of gear; they are brought to rest with their doors downwards. These being unfastened and opened, the powder is delivered into casks. The operation produces a small quantity of dust, which is removed by passing the glazed powder once through a slope reel.

At this stage of manufacture, powder contains a degree of moisture which must be extracted before the powder is fit for use or for storage; this is effected in the drying stove, where both fine and large grain powder can be dried at the same time.

THE DRYING STOVE.

The drying stove is a close chamber heated to a high temperature by steam; the doors and windows of the building are double to prevent the loss of heat; the interior is fitted with an open framework of wood to support the trays upon which the powder is spread. A series of cast-iron steam pipes (Plate V, Fig 10), of twenty-two lengths, each about 11 feet long, with an external diameter of 7½ inches, are laid a few inches above the floor; these pipes are arranged horizontally, with an inclination of 1 inch in 11 feet from the end where they are connected to the main steam supply pipe, which is in direct communication with the boiler; the quantity and supply of steam is regulated by a stop valve.

As the steam condenses, the water runs through a small wrought-iron pipe attached to the ends of the large ones; these drain pipes are bent so as to allow for the expansion and contraction of the large pipes, each length of which is supported on four rollers fitted into cast-iron brackets, allowing freedom of motion laterally. The small pipes conduct the distilled water into a main cast-iron pipe which conveys it into a close tank, whence it is taken to the incorporating mills and used for dampening the charges. The drying stove is about 32 feet in length by 30 feet in width, and from 10 to 11 feet in height; affords about 10 cubic feet of space to every square foot of heating surface.

A wooden staging erected immediately over the pipes supports the trays; these are wooden frames with canvas bottoms, each being 3 feet in length by 2 feet 6 inches in width, and about 1¼ inches deep, upon each of which from 6 pounds to 8 pounds of gunpowder is spread out evenly. The stove contains 256 trays, and from 30 to 40 barrels of powder can be dried at one time.

It requires about four hours to heat the stove to a temperature of 130° Fahr., to which the powder is subjected. The temperature is observed without entering the drying stove by a large thermometer inside the window. The powder is subjected to the full heat for sixteen to eighteen hours, the stop valve then closed, and the chamber allowed to cool. In two to three hours the trays may be removed. One stove can dry a full charge every twenty-four hours; if the factory is large two stoves are required, with the steam boiler between them to work them alternately. The heat must be applied slowly or the texture or shape of the grain is apt to change by being cracked or burst into pieces. The moisture must be carried away as it arises, to prevent injury to the grain; the roof and bottom of the drying stove have ventilators for its escape. The ventilators can be opened from the outside. When no more vapor arises, the ventilators are closed and the powder subjected to the hot dry air a few hours before opening the doors.

In drying powder a small quantity of dust is produced, which is removed by a dusting wheel. Large grain powder is reeled for half an hour in a horizontal reel covered with canvas, having twenty-four meshes to the inch, to clean it from dust and give a fine finished gloss.

Fine-grain powder is run for two hours through a similar slope-reel covered with canvas, having twenty-eight meshes. It is put in barrels provided with copper or ash hoops, the heads of which are branded with the size and kind of powder. The gunpowder is now ready for use or storage.

In a given quantity of "mill-cake" the proportions obtained are as follows: About seven-tenths large grain, two-tenths fine grain, and one-tenth dust; in damp weather, however, these proportions are somewhat altered, the dust being considerably increased.

PACKING.

Government powder is packed in barrels of 100 pounds each. Powder barrels are made of well seasoned white oak, and hooped with hickory or cedar hoops, which should be deprived of their bark; the cedar is not so liable as hickory or white oak to be attacked by worms, and it should therefore be used in preference; or the hoops may be prepared by immersion in a solution of corrosive sublimate. The hoops should cover two-thirds of the barrel. Fine grain powders may be packed in canvas bags before being barreled. Instead of a bung on the side, a screw-hole 1.5 inches in diameter is made in the head of the barrel, for mortar and

musket powder; it is closed by a wood-screw with an octagonal head, which must not project beyond the ends of the staves; under the head of the screw is a washer of thin leather, steeped in a solution of beeswax in spirits of turpentine. This screw-plug renders it unnecessary to take out the head of the barrel, and the hoops may therefore be secured with copper nails; for transportation, a piece of cloth should be glued over the head of the plug. Some barrels have been made with six copper hoops, and others with four copper and eight or ten cedar hoops; the copper hoops are one inch wide and one-eighth of an inch thick, fastened with two rivets and nailed each with three copper nails 0.625 inch long. Average weight of a hoop 2¼ pounds.

Powder boxes lined with galvanized iron and copper with large screw lids are now on trial, holding 100 pounds.

It has been found that lining powder barrels with India-rubber cloth has an injurious effect on the powder in consequence of the affinity of the caoutchouc for sulphur.

The heads of powder barrels are painted *black* in order to show the *marks* more plainly in dark magazines.

DIMENSIONS OF POWDER BARRELS.

Whole length	20.5 inches.
Length, interior, in the clear	18 inches.
Interior diameter of head	14 inches.
Interior diameter of bilge	16 inches.
Thickness of the staves and heads	0.5 inch.
Weight of the barrel	25 pounds.

The barrels have generally 12 hoops, 14 to 16 staves, and two or three pieces in each head. The dimensions are such that with 100 pounds of powder there shall be a vacant space in the barrel to allow for shaking to prevent caking. The barrel will hold about 120 pounds settled by shaking.

INSPECTION OF POWDER.

The inspector of gunpowder should satisfy himself before its reception as to the purity of the ingredients employed by the manufacturers, and that their proper preparation and careful manipulation through all the various stages of manufacture have been rigidly observed.

Before powder for the military service is received from the manufacturer, it is inspected and proved. For this purpose at least 50 barrels are thoroughly mixed together. One barrel of this is proved.

Musket powder should be fired three rounds with service charges.

Mortar and cannon powder should be fired three rounds with heaviest charges in a field and siege gun respectively.

Mammoth, hexagonal, cubical, prismatic, or other special powders, three rounds with battering charges from the guns in which these powders are to be used.

The density and granulation of the powder, as well as the velocity and pressure obtained in its proof, should conform to the Ordnance regulations in these respects, for the particular service or piece for which the powder is required, within the allowed limits of variation.

GENERAL QUALITIES.

Gunpowder should be of an even-sized grain, angular and irregular in form, without sharp corners and very hard. When new, it should leave no trace of dust when poured on the back of the hand, and when flashed in quantities of 10 grains on a copper plate it should leave no bead or

foulness. It should give the required initial velocity to the ball, and not more than the maximum pressure on the gun, and should absorb but little moisture from the air.

SIZE OF GRAIN.

The size of the grain is tested by standard sieves made of sheet brass pierced with round holes. Two sieves are used for each kind of powder, Nos. 1 and 2 for musket, 3 and 4 for mortar, 5 and 6 for cannon, and 7 and 8 for mammoth powder.

A compact shape of grain, approaching the cube or sphere, is desirable. Elongated flat scales are objectionable. The number of grains in several weighed samples should be counted.

Diameter of holes for musket-powder.....No. 1, 0.03 in.; No. 2, 0.06 in.
Diameter of holes for mortar-powder .....No. 3, 0.10 in.; No. 4, 0.25 in.
Diameter of holes for cannon-powder .....No. 5, 0.25 in.; No. 6, 0.5 in.
Diameter of holes for mammoth-powder ..No. 7, 0.75 in.; No. 8, 0.9 in.

Hexagonal, Cubical, Prismatic. } Dimensions of these powders vary with the caliber of the gun in which they are used, and have not as yet been definitely determined upon in our service.

GRAVIMETRIC DENSITY

Is the weight of a given measured quantity. It is usually expressed by the weight of a cubic foot in ounces. This cannot be relied upon for the true density when accuracy is desired, as the shape of the grain may make the denser powder seem the lighter. Its only value is a fair idea of the value of air space in a given weight.

If W = weight in ounces of one cubic foot of homogeneous powder, or the specific gravity $\times$ by 1,000 (assumed weight of a cubic foot of water at 1,000 ounces);

W' = weight in ounces of one cubic foot of same powder granulated, or ascertained gravimetric density:

then

$$\frac{W'}{W} = P = \text{proportion or percentage of the cubic foot occupied by the powder,}$$

and

$$1 - P = P' = \text{proportion or per cent. of the cubic foot occupied by the air.}$$

SPECIFIC GRAVITY.

The specific gravity of gunpowder varies from 1.65 to 1.8. It is important that it should be determined with accuracy. Alcohol and water saturated with saltpeter have been used for this purpose; but they do not furnish accurate results. Mercury only is to be relied upon.

Hardness is tested by breaking the grains between the fingers; the hardness is judged of by experience.

THE MERCURY DENSIMETER.

It is very necessary that the density or specific gravity of the powder should be most accurately determined. For this delicate operation a very ingenious instrument has been devised by Colonel Mallet, of the French army, called a Mercury Densimeter.

On a small table a kind of barometer is fitted (Plate VI, Fig. 14), but instead of the glass tube being closed at the upper end and all in one piece, as is usual, it is in this case made in two pieces and open at the top. The upper part is about 24 inches in length, and is connected to the lower, which is 10 inches in length, by means of a closely fitting and perfectly air-tight screwed metal joint; the lower part, instead of being a plain parallel tube of the same diameter throughout as the upper, is made in the form of a globe or bulb, and on the neck at each end of it a metal union and stop-cock are secured, both of which are made perfectly air-tight. By means of one of these unions this glass globe or lower half of the instrument is attached to the upper, while the other union, into which is screwed an open nozzle or metal tube, dips into a cup fastened to the table filled with mercury. On another table standing by the side of the first one an ordinary air-pump is fixed, with vacuum gauge, &c.

It will readily be seen that if the upper part of the glass tube of the densimeter be connected with the air-pump, and the air be extracted from the glass tube whilst the lower tap is closed, a vacuum will be formed, and that upon opening the lower tap so as to afford a free passage for the mercury in the cup, it will rise and fill the glass globe and upper portion of the tube to such a height as will balance the pressure of the atmosphere, thus giving a column of mercury of precisely the same total height as that in an ordinary barometer.

To use the instrument, two tables are placed side by side, the open upper end of the glass tube of the densimeter is connected with the air-pump by means of a flexible tube, the tap on the upper union of the densimeter is opened, the lower one is closed.

The air-pump is worked; as soon as all the air is exhausted, shown by a vacuum gauge attached to the air-pump, the lower tap on the glass tube immediately below the globe is opened, and the mercury rushes into the tube; when it ceases to rise, the two metal taps are closed, and the globe part, with the mercury contained therein, is removed and carefully weighed. All the mercury is now emptied back again into the cup, and the globe, nearly filled with a known weight of gunpowder, say 100 grammes, is then reconnected to the densimeter under the same conditions as before, and the air again exhausted until a vacuum is formed. The lower tap is now opened, and the mercury allowed to find its way in and rise in the tube; the mercury rises to precisely the same height in the tube as before; but the globe having been nearly filled with gunpowder will contain less mercury. The taps on the lower portion of the instrument are closed, the globe part removed and again weighed. This weight, as well as that previously ascertained when the globe was entirely filled with mercury, is recorded, and from these two ascertained weights the density of the powder can readily be obtained by the following rule:

To find the density of the gunpowder, we have only to multiply the specific gravity of the mercury by the weight of the gunpowder placed in the globe of the densimeter, and divide by the difference in weight of the globe when filled with mercury only and when filled with gunpowder and mercury, plus the weight of the powder placed in the globe; the result will show the density of the gunpowder under test.

EXAMPLE.

	Grammes.
Suppose the weight of globe when filled with mercury to be	3,100
And the weight of globe when filled with mercury and gunpowder to be	2,400
The difference would be	700

S. G., specific gravity of the mercury.
W. G. P., weight of gunpowder in the bulb.
D. W., difference in weight of globe when filled with mercury only, and when filled with gunpowder and mercury.

$$\text{then } \overset{\text{S.G.}}{13.57} \times \overset{\text{W.G.P.}}{100} = 1357.00$$
$$\text{and } \overset{\text{D.W.}}{700} + \overset{\text{W.G.P.}}{100} = 800 \qquad \frac{1357.00}{800} = 1.696, \text{ the density of the gunpowder tested;}$$

SPECIFIC GRAVITIES OF LARGE-GRAINED POWDERS.

The instrument employed for determining the specific gravities of large-grained powders was constructed after the plan of one designed by the Messrs. Du Pont de Nemours & Co., and employed by them with very satisfactory results at their works near Wilmington, Del. It is a mercury densimeter, adapted, by its construction, to the reception of large grains, and having capacity for five pounds of powder, which, for convenience, is the weight of sample always employed. It differs, however, from the small densimeter in ordinary use by a combination of the different parts, such that, the reservoir for containing the powder and mercury to be weighed, and the balance by means of which the weighings are made, are assembled together in one instrument. The balance also is so adapted to its special purpose as to simplify considerably the subsequent process of calculation. A great saving of labor and time is gained by this form of the instrument, and the occurrence of breaks and leaks, so frequent in the smaller one, is in great measure avoided. Again, from the much larger sample of powder employed, a fair representative result of the specific gravity of the entire lot is more likely to be secured.

DESCRIPTION OF THE INSTRUMENT.

Plate VII. To describe more particularly, the instrument consists of three principal parts, to wit: A beam-scale, A, a reservoir, B, to contain the powder and mercury to be weighed, and a bowl, C, to contain mercury alone. In connection therewith, an air-pump, D, is employed, the cylinder of which has communication with the interior of the reservoir through a rubber tube leading from the nozzle *z*, of the pump, to the glass tube *a*, at the top of the reservoir. The balance is suspended from a hook, *b*, firmly secured to the roof of the housing, and its axis of suspension is a knife-edge lying in the same plane with the axes of suspension of the rods *c* and *d* and of the reservoir B. Platforms *e* and *f* are attached to the suspension rods *c* and *d*, on which to place the weights. The latter consists of pounds, tenths of a pound, and five-hundredths of a pound, marked in reference to the weights they will balance in the reservoir, and of a large unmarked weight W, termed the *counterpoise*. This counterpoise has a cavity bored in it lengthwise, the use of which will appear hereafter; its weight is about 8 pounds. The long arm of the beam is also graduated, and by means of "riders," or sliding weights, the weighings can be made to hundredths and thousandths of a pound; the graduated edge of the beam is in the same plane with the knife-edges. *h* and *i* are counterpoises admitting of movement on screw spindles passing through them, in directions that are respectively parallel and perpendicular to the beam. The former is used to adjust the arms to the same weight, the latter to regulate the sensibility of the beam. In connection with the counterpoise *h*, a light wire *k* is sometimes used along the beam to facilitate the adjustment of the arms. The beam and its appurtenances proper are of brass.

The reservoir B is of cast iron, and swings on trunnions in the yoke E. It also admits of a horizontal angular movement about the vertical pivot *l*, connecting the yoke with the supension stirrup *m*. A screw-cap, *n*, fitted with a leather washer, covers the mouth of the reservoir, and when removed, for the purpose of introducing powder, is attached to the hook *o*, on the outside of the yoke, so as to be included in the weighing. The mercury is admitted, or withdrawn, through the stop-cock *s*.

The conical ends of the reservoir are cast in separate pieces and are afterwards screwed on to the cylinder, the joints being well leaded. Careful workmanship is requisite to prevent the formation of a ledge, or recess, at these joints, which might serve to retain sufficient portions of the mercury to affect the accuracy of the subsequent weighings.

The diaphragms of wire and of leather, usually employed to cover, respectively, the upper and lower apertures of the reservoir, are not required in this instrument. The capacity of the reservoir is about 78 pounds of mercury, or 40 pounds of mercury and 5 pounds of powder. The mouth is 2½ inches in diameter, and the sample of powder fills the reservoir to about the top of the cylindrical portion. The weight of the reservoir is 20½ pounds.

The bowl C is of cast iron, and, by means of the crank H, can be raised or lowered vertically. An outlet pipe, *p*, at the bottom of the bowl, and furnished with a stop-cock, permits the discharge of the mercury when desired.

The air-pump is one of Ritchie's, in which, the cylinder remaining stationary, the oscillation takes place in the connecting-rod, which communicates the motion of the handle to the piston-rod.

PROCESS OF DETERMINING THE SPECIFIC GRAVITY OF A SAMPLE OF POWDER.

The beam is first accurately balanced by means of the counterpoise *h*, and the bowl filled with mercury and run up till the nozzle of the reservoir is well immersed below the surface. The large counterpoise W is then placed on the platform suspended from the shorter arm, the rubber hose slipped over the top of the glass tube of the reservoir, the air exhausted by means of the pump, and the stop-cock *s* opened to admit the mercury. The pumping is continued during the ingress of the mercury, and when the latter has risen to a fixed mark, indicated on the glass tube, the stop-cock is closed and the rubber hose removed. Usually it is necessary to run off a little of the mercury and lower its upper surface to the fixed mark. The balance of the beam is now restored by dropping fine shot into the cavity of the counterpoise W, the weight of the latter being slightly less than the weight of the filled reservoir; this done, the stop-cock *s* is opened and the reservoir emptied. The counterpoise W is then replaced by the 5-pound weight, the screw-cap removed and hooked to the yoke, and a sufficient quantity of the powder to be tested introduced into the reservoir to balance the 5-pound weight. The screw-cap is then replaced, the counterpoise W added to the 5-pound weight, and the reservoir filled with mercury, by means of the air-pump, to the same height as before. The equipoise is now restored (the rubber tube having been removed) by placing weights on the platform suspended from the longer arm of the beam, and, in addition, by the "riders" on the beam, if necessary. The sum of these weights is the weight of the mercury displaced by the powder, or of a volume of mercury equal to the volume of the powder, and the specific gravity of the latter results from

the well-established principle that the specific gravities of two substances are proportional to the weights of equal volumes of those substances.

Denote the sum of the weights on the longer arm by W′, the weight of the powder by *w*, and the specific gravity of the mercury at the temperature of the time of observation by D, and we shall have for the specific gravity of the powder, denoted by *d*:

$$d = D \frac{w}{W'}$$

In the use of this form of the densimeters the weighings not only are rapidly and accurately made, but, it is to be observed, the actual weights required for the computation are obtained directly by a discriminative process peculiar to the balance. To simplify further, the weights for the longer arm are marked double their actual value in reference to the reservoir, so that in the computation the specific gravity is obtained by setting the decimal point in the value of D one place farther to the right, and dividing by the value of W′, as indicated on the weights, the effect being the same as multiplying by 2 both terms of the fraction $\frac{w}{W'}$.

Form of record of computation.

Sample.	Double weights corresponding to equal volumes of—		Temperature of mercury.	Specific gravity of mercury corresponding to observed temperature.	Specific gravity of powder, $\frac{10 \times D}{W'}$
	Powder, *w*.	Mercury, W′.			
Du Pont's hexagonal F. U.	10	76.94	69°	13.54688	1.7603

Owing to the considerable bulk of the sample employed with the large densimeter, and the comparatively large weights of powder and mercury that consequently enter the formula for the computation of the specific gravity, very close weighing with this instrument is not absolutely requisite. A variation, for instance, of 46 grains in the actual value of *w*, or of 350 grains in that of W′, would affect the resulting specific gravity by only two points in the third place of decimals. This feature is one of great practical utility, as it enables us to dispense with very small weights, and to abridge considerably the operations of weighing.

INITIAL OR MUZZLE VELOCITY.

This is determined by any of the electro-ballistic machines available; the Boulengé chronograph is one of the simplest and most generally used for proof of powder. For a full description and use of the instrument, see Ordnance Memoranda, No. 25.

STRAIN UPON THE GUN.

This is determined by the Rodman pressure-gauge. For description and use of the instrument, see Ordnance Memoranda, No. 25.

DETERMINATION OF MOISTURE AND RESISTANCE TO MOISTURE.

The amount of moisture in powder is determined by drying samples in an oven with a water bottom (Plate X*a*). A vessel of tin, double-

walled, except the face containing the door, is fitted at the top with an opening for the introduction of water; the door is double; the inner skin lining has perforations at the top to allow the escape of moisture given up by the powder. Ledges on the inside of the oven support the powder trays. Before use, the water space is filled with boiling water; a spirit lamp keeps up the heat; the supply of water is kept up to compensate for evaporation.

The powder is subjected to heat as long as it loses weight, the loss indicating the percentage of moisture driven off. On being removed from the oven it should be transferred at once to perfectly clean, dry, air-tight weighing bottles.

The ability to resist moisture is determined by subjecting samples which have been dried to exposure, first in open air, then in a hygroscope containing a solution of niter at 100° cooled to 80° Fahr.

The hygroscope (Plate X*b* is an air-tight box in which the powder is subjected to a damp atmosphere at a uniform temperature for 24 hours. It consists of a box lined with copper, with a space of two inches between packed with hair. The lid is double also, like the sides, in construction; an India-rubber gasket covers the edges of the top, which is screwed firmly down with thumb-screws. Inside the box is a movable perforated tray of copper resting on ledges 8.5 inches by 8.5 inches. The intervening spaces have water-tight trays on ledges filled with a solution of niter.

The powder to be tested is placed in circular cups of copper with fine wire-gauze bottoms, affording free access of moisture to all parts of the sample under test. The percentage of gain is determined by weighing the powder in carefully prepared bottles on opening the hygroscope. A careful record is kept of the barometer, hygrometer, external and maximum and minimum internal thermometers.

INCORPORATION.

On breaking the grains, a fine uniform ashen-gray color throughout should appear; the grain texture should be close, without white specks even when magnified. "Flashing" on glass or porcelain plates, small copper measures for fine-grain powders inverted on the plates, keeps the heap nearly the same at each trial. The powder should be in small conical heaps; if the incorporation is good, only smoke marks remain on the plate after flashing; if bad, specks of undecomposed niter and sulphur will form a dirty residue. The test requires experience to insure good judgment.

The relative incorporation is determined by the balance; the greater increase of weight on the plate, the less satisfactory the powder in this respect. Moist powder flashes badly.

ANALYSIS OF GUNPOWDER.

Pulverize 75 grains, place in a glass beaker with eight ounces of distilled water; stir rapidly with a glass rod; when clear, test with litmus paper for acids and with tumeric for alkalies. Wash repeatedly to remove all the sulphur and charcoal, and examine the residuum with a microscope for coarse particles of either or foreign substances. Determine the amount of moisture by placing 45 grains of powder, ground fine, in a watch crystal, dry thoroughly, and cover the crystal with an-

other. The weight of dish and cover being known, the loss of weight due to moisture contained in them is found.

DETERMINATION OF THE SULPHUR.

Put the 45 grains of dry powder in a pipette, having a wad of heated asbestos in the narrow part; verify the weight of the pipette and wad; insert the pipette into a hole in the cork of a small weighed flask; treat the powder with 50 *c c* of rectified bisulphide of carbon, remove the pipette and cork, recork the flask, and distil off the bisulphide of carbon for future use.

A sand-bath is used during distillation, which must proceed very slowly, the flask being raised above the sand, which must not become too warm. The percentage of sulphur is calculated from the weight thus obtained. One-tenth per cent. is added to the amount of sulphur, as that quantity generally remains in the powder after the treatment with the bisulphide of carbon.

DETERMINATION OF NITER.

The pipette containing the residue is fixed in a small weighed flask, the portion above the crook being wrapped in muslin. The tube of the flask is connected with an air-pump by a rubber tube, and the contents of the pipette treated with 40 *c c* of distilled water; work the pump carefully to allow the water to enter the flask by drops; to prevent crystallization of the dissolved niter in the narrow part of the pipette, cold water is first used, then warm, and lastly hot. Drench the muslin on the pipette with water of the same temperature as that for dissolving the niter. When the flask contains 40 *c c* of the niter solution, remove the pipette and evaporate the water on a sand-bath, removing the flask occasionally, and cool as the solution becomes saturated. When the niter is crystalized, it is heated until it and the flask are quite dry; the weight of the niter is then taken.

DETERMINATION OF THE CHARCOAL.

The asbestos wad and a large part of the charcoal are pushed out of the pipette by a wire into a watch glass; the pipette and watch glass and contents dried and weighed; the weight of the pipette, watch glass and abestos being known, that of the charcoal is obtained. The weight added to the sulphur is of course deducted.

INSPECTION REPORT.

The report of inspection should show the place and date of fabrication and of proof, the kind of powder and its general qualities, as the number of grains in 100 grains, its specific gravity; whether hard or soft, round or angular, of uniform or irregular size; whether free from dust or not; the initial velocities and pressures per square inch obtained in each fire; the amount of moisture absorbed; and, finally, the height of the barometer and hygrometer at the time of proof.

MARKS ON THE BARRELS.

Each barrel is marked on both heads (in white oil-colors, the head painted black) with the number of the barrel, the name of the manu-

facturer, year of fabrication, and the kind of powder, *cannon*, *mortar* or *musket*, &c., the mean initial velocity, the pressure per square inch on the pressure-piston, and density. Each time the powder is proved, the initial velocity is marked below the former proofs, and the date of the trial opposite it.

RESTORING UNSERVICEABLE POWDER.

When powder has been damaged by being stored in damp places, it loses its strength, and requires to be worked over. If the quantity of moisture absorbed does not exceed 7 per cent., it is sufficient to dry it to restore it to service. This is done by exposing it to the sun, or in a drying room.

When powder has absorbed more than 7 per cent., of water, it is sent to the powder-mills to be worked over, or sold as condemned powder.

When it has been damaged with salt water, or become mixed with foreign matters which cannot be separated by sifting, the saltpeter is dissolved out from the other materials and collected by evaporation.

Proportions of ingredients.

	Saltpeter.	Charcoal.	Sulphur.
By the atomic theory	74.64	13.51	11.85
In the United States:			
For the military service (the latter proportion is generally used)	76. 75.	14. 15.	10. 10.
For sporting	78. 77.	12. 13.	10. 10.
In England, same as United States:			
For the military service	75.	15.	10.
For sporting	78. 75.	14. 17.	8. 8.
In France (Wetteren powder has given best results; many experiments have been made with varying proportions):			
For the military service	73.775	14.205	12.02C
For sporting	78.	12.	10.
For blasting	62.	18.	20.
In Prussia, same as England and United States:			
For the military service	75.	15.	10.
In Spain:			
For the military service	76.5	12.7.	10.8
In Austria:			
For the military service	74.	16.	10.

PRESERVATION, STORAGE, AND TRANSPORTATION.

In the powder-magazines the barrels are generally placed on the sides, three tiers high, or fours tiers, if necessary. Small skids should be placed on the floor and between the several tiers of barrels, in order to steady them, and chocks should be placed at intervals on the skids to prevent the rolling of the barrels. The powder should be separated according to its kind, the place and date of fabrication, and the proof-range. Fixed ammunition, especially for cannon, should not be put in the same magazine with powder in barrels, if it can be avoided.

Fireworks should never be stored in powder magazines.

In a room 13 or 14 feet wide, the barrels may be arranged in a double row in the center, two alleys 2½ feet wide, and two single rows 6 to 12 inches from the walls; in this way the marks of each barrel may be seen and any barrel can be easily reached. In a room 12 feet wide, an equal number of barrels may be placed in two double rows, with a central alley of 3 feet, and two side alleys, next the walls, of about 10 inches

each. There should be an unencumbered space of 6 or 8 feet at the door or doors of the magazine.

Should it be necessary to pile the barrels more than four tiers high, the upper tiers should be supported by a frame resting on the floor; or the barrels may be placed on their heads, with boards between the tiers.

Besides being recorded in the magazine book, each parcel of powder should be inscribed on a ticket attached to the pile, showing the entries and the issues.

For the preservation of the powder and of the floors and lining of the magazine, it is of the greatest importance to preserve unobstructed the circulation of air under the flooring as well as above. The magazine should be opened and aired in clear, dry weather, *when the temperature of the air outside is lower than that inside the magazine.* It should not be opened in damp weather if it can be avoided. The ventilators must be kept free; no shrubbery or trees should be allowed to grow so near as to protect the building from the sun. The magazine yard should be paved and well drained. The moisture of a magazine may be absorbed by chloride of lime suspended in an open box under the arch, and renewed from time to time; quicklime is dangerous, and should not be used.

The sentinel or guard at a magazine, when it is open, should have no fire-arms, and every one who enters the magazine should take off his shoes, or put socks over them; no sword or cane, or anything which might occasion sparks, should be carried in.

The windows should have inside shutters of copper wire-cloth. Fire should never be kindled near the magazine for the repair of the roof or lightning rods.

Barrels of powder should not be rolled for transportation; they should be carried in hand-barrows, or slings made of rope or leather. In moving powder in the magazine, a cloth or carpet should be spread; all instruments used there should be of wood or copper, and the barrels should never be repaired in the magazine. When it is necessary to roll the powder for its better preservation and to prevent its caking, this should be done, with a small quantity at a time, on boards in the magazine yard.

In the spring an inspection of the barrels should be made, and the hoops swept with a brush wherever they can be got at, to remove the insects which deposit their eggs at this season.

In wagons, barrels of powder must be packed in straw, secured in such a manner as not to rub against each other, and the load covered with thick canvas.

In transportation by railroad, each barrel should be carefully boxed and packed, so as to avoid all friction. The barrels should have a thick paulin under them. The cars should have springs similar to those of passenger cars.

MAGAZINES.

A plan, sections, and elevations of a magazine approved by the War Department is shown on Plate XI. It is built of brick, the walls are 1.5 feet thick, provided with air-chambers and ventilating passages, connecting with the interior of the magazine and exterior air. A, are the air chambers in the body of the wall; B, communications between air chambers and interior of magazine; C, air-passages; D, communications between upper and lower air-passages; E, communications between upper air-passages and exterior air; F, communications between lower air-passages and interior of magazine; G, lower surfaces of projections of the roof, to be sealed with tin, perforated with small holes,

and painted on both sides to obtain free circulation of air under the roof. The covering of the roof is slate; gutters and spouts copper. The ceiling is composed of light flat arches sprung from iron beams. For details of construction, see Plate XI.

A magazine 60 by 40 feet, of this construction, is ample for the service of most of our arsenals.

A small vestibule with double doors may be added. An interior door of wire should be provided, and wire screens for the two windows at the end of the magazine opposite the door. The interior of the magazine may be sheathed to a height of 5 feet, with clear narrow boards, one inch from the walls.

Magazines at arsenals should be, when practicable, protected by artificial traverses, and located as far from other buildings as the arsenal site will admit. The site should be thoroughly drained.

For powder depots, magazines of a capacity of 5,000 barrels should be built in preference to smaller ones; they should be protected from each other by hills, natural or artificial traverses; be located far away from other powder-mills or laboratories and buildings on the reservation, and capable of thorough drainage and free ventilation.

Service magazines constructed of light wrought-iron beams, sheathing, &c., with working drawings, were furnished the department by the late General Rodman, in 1866. In future constructions, this or some kindred plan will, no doubt, be fully considered.

POWDER DEPOTS.

Large depots for storage of powder, materials for its manufacture, and a powder factory for making experimental powders, establishing the best method of insuring uniformity of manufacture of service powders, and maintaining a high uniform standard of the various kinds of powder required for small-arms, field, siege, and heavy ordnance obtained from private manufacturers, has been long recognized as a paramount need of the Ordnance Department.

One such depot, for storage of powder only, has been established near Saint Louis; a part of the government reservation at Jefferson Barracks having been taken for the purpose, and a number of magazines capable of storing 50,000 barrels of powder erected. The ground selected is suitably located and isolated, well drained, the magazines separated from each other, and protected by natural traverses. It has also convenient railroad and water connections with the West, South, and Northwest.

A suitable large powder-depot with government powder-mill is now greatly needed on the Atlantic coast. Surveys of tracts have been and will be be made and a suitable one recommended, the following considerations governing its selection:

1st. That the depot should be in a region of country which does not admit of being populated, so that destruction of life and property in case of accident would be a minimum.

2d. The tract should be sufficient in extent to contain suitable positions for magazines for storage of 10,000 tons of powder, material for its manufacture, &c., and the necessary buildings for a government powder-mill.

3d. It should be near enough to rail and water transportation to afford facilities of transportation to the seaboard, interior, and the lakes, having a short line of government railroad connecting the site with rivers and trunk-lines.

Magazines at our arsenals are of but limited capacity, and endanger large amounts of public as well as private property, and have become a great source of complaint. Storage of powder at the magazines of our seaboard forts is very objectionable, as powder so stored deteriorates very rapidly. At present there are on hand 2,500 tons of powder and 3,000 tons of niter stored at insecure and unsuitable places, which should be properly provided for without unnecessary delay.

LIGHTNING CONDUCTORS.

(Condensed from a "Circular memorandum" issued by General Burgoyne, inspector general of fortifications, British army, from the researches of Sir William Snow Harris, F. R. S., 1858.) Plate XII.

It appears to be established—

That metal in a building, whether disposed of in the form of a conductor or otherwise, never *attracts* lightning.

That, provided the surfaces of metals are not interrupted by bodies possessing a less conducting-power, a building entirely of metal will be the safest of all, and that such buildings require no further lightning-conductors than connection with the earth over the masonry foundations on which they are often laid.

That, with regard to a building of brick or stone, the object must be to establish a sufficient number of lines of electrical conductors, extending from its most elevated and prominent points to the ground; and, further bring the building into a condition similar to that of a metal building by means of other conductors generally attached to more prominent lines of the building itself, such as the ridges, angles, and eaves.

There is no advantage, but the contrary, in endeavoring to insulate the conductors from the building.

The best material for conductors is copper, either in tubes 1½ to 2 inches diameter and .125 inch to .2 inch thick, or wire rope.

All metal surfaces, whether lead, copper, or iron, on ridges, roofs, gutters, or coverings to doors or windows, to be connected by plates of copper with the conducting system. Lead, on account of its low conducting-power, cannot be altogether depended upon.

One or more solid copper rods, to project freely into the air, about 5 feet above the highest points of the building to which the main conductors are applied. The summit of the rod to be pointed; but gold, gilt, or platinum tops are unnecessary.

The termination of the conductors below to be led into damp or porous soil when the building happens to stand upon it; but, when the soil is dry, two or three trenches to be cut, radiating from the foot of the conductor to a depth of 18 inches or two feet and 30 feet in length, and either the conductor carried along the bottom of the trenches or old iron chain laid in them, carefully connected with the foot of the conductor. The trenches to be then filled up to one foot in depth with coal-ashes or other carbonaceous substance, and afterwards with earth or gravel.

If it be possible, in regulating the surface drainage, to lead a flow of water, during the rain which generally accompanies thunder-storms, over the site of the trenches, it will be an additional precaution.

Tanks are useless, except where the water flows freely into them from the surrounding soil, and even then they are superfluous as appendages to the conductors.

The conductors for brick or stone magazines with slate roofs should consist of a sheet-copper strip 4 inches wide and .125 inches thick, covering the ridge and securely fixed to it by wrought-copper nails. At each

end of the ridge a solid copper rod .5 inch in diameter is fixed to the conductor on the ridge, and projects about 5 feet above the highest point of the building; its upper end is pointed.

Copper strips 3 inches wide, or copper tubes one inch in diameter, pass down the angles of the hip, and are firmly secured to the copper eaves-gutter.

The descending water-pipes, made also of copper, and fastened to the face of the building by copper holdfasts, are connected at their lower end to the underground conductor by a piece of copper, 3 inches wide, wrapped around the lower end of the water-pipes and riveted to the underground conductor.

The underground conductor runs out from the building 4 feet, and then branches into two parts, each 8 feet long, 2 inches wide, and .125 inch thick. These conductors are about 2.5 feet from the surface of the ground at the lower end, and are covered with coal ashes and earth.

The copper sheathings on the doors and windows are connected with the lower end of the water-pipes by flat copper strips, 2 inches wide, fixed to the water-table by copper nails driven into wooden plugs about 10 feet apart.

When tubular conductors cannot be had of sufficient length in one piece, they are connected by a union joint, and strengthened by a small pipe or ferrule, about 4 inches long, inside the tube, and riveted to each end.

Buildings which have the eaves-gutters and down-pipes made of tin or zinc should have a main conductor communicating directly with the ground; it should also be connected with the eaves-gutters, and the down-pipe should connect by a metallic communication with the ground, running out some distance from the building.

In case of buildings situated on a dry or rocky soil, especial pains must be taken to lay down old chains or other conductors in various directions, to a distance of 10 to 15 yards, and from 1 foot to 1.5 feet below the surface of the ground; and, if possible, lead a flow of rain over the surface of the ground about or near the conductor. Let the conductor terminate in a large surface of moist earth whenever it can be effected.

If copper be not used for conductors, zinc is the next best material of which they can be made. If iron be used, it should be in the shape of galvanized wrought-iron pipe, not less than 2 inches in diameter, firmly screwed together in joints of extra thickness.

Copper tube, of a thickness of from .125 to .2 inch is always to be preferred: it has more than five times the capacity for conducting electricity than iron has, and more than three times that of zinc.

SPECIAL POWDERS.

For some years, it has been a recognized fact, that the ignition, combustion, and explosive effect of gunpowder depend, in a great degree, on the size, shape, and density of the grain, and that guns of different calibers require for their most efficient service powders differing in these features in order to secure the best results. The rapid increase in weight of projectiles with the increase in caliber of guns, and the comparatively smaller power of resistance of the guns, renders it necessary that the rate of combustion of the charge be regulated, so as to reduce the strains on the guns as much as possible, while at the same time preserving high initial velocity to the projectile, thus rendering practicable the use of the heaviest guns, projectiles, and charges.

The amount of gas evolved at the first instant of inflammation and com-

bustion is measurably controlled by the size and form of grains, offering a lesser surface of ignition, and the increased density, offering greater resistance to the penetration of the hot gases through the grains, graduates its rapidity of burning. The form of grain affecting the amount of surface exposed to combustion—that shape which offers a comparatively small surface at the first instant of ignition, increasing progressively—is theoretically the best.

Experiments by all civilized nations have settled beyond cavil the important part played by powders suited in the above qualities to the guns in which they are to be used, and have led to the adoption of large-grain powders in heavy guns, resulting in the production, among the best, of mammoth, pebble, cubical, hexagonal, and perforated prismatic powder; the honor of the first investigation and practical results in this direction, being universally awarded to the late General Rodman, Ordnance Department, U. S. A.*

Nearly all the great powers of Europe have powder-mills under the immediate supervision of their own officers and agents; and the quality of powders made at them is held deservedly in high estimation. While these mills are insufficient for supplying all the wants of the respective governments, the great care in selection and manipulation of the best materials, and close attention to every detail of manufacture, serve to maintain a high standard of quality of powder, and regulate the price and excellence of that necessarily obtained from private manufacturers. The United States would profit by following so excellent an example, by establishing a powder-mill, under official direction, of limited capacity.

The royal gunpowder factory of England is located at Waltham Abbey; those of Russia are the Ohktenskoi; the Michael-Schosta (saltpeter district); the Kazan (at which most powders for military and naval service are made).

Germany obtains her powders, in part, from the government factories at Spandau and Neisse; the standard quality of that procured from private factories being regulated by the former.

France now has five gunpowder-works—Ripault, Bouchet, Saint Chamas, Angoulême, and Esquerdes.

Belgium has a large powder-mill at Wetteren, and produces large-grain powders of most excellent quality.

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*The late General Rodman, one of the original devisers of improvements in heavy gun constructions, experimented as early as 1860 with mammoth-grain powders, and developed their use in the United States, in the heavy smooth-bore guns bearing his name, and its heavy rifle guns. His ingenious and fruitful mind led him a little later to seek a solution of the problem of increased endurance of heavy ordnance by better controlling the combustion of powders, in the use of various sizes, forms, and increased densities of grain. General Rodman was the pioneer in the investigation of several forms of large-grain powders, as pebble, lenticular, perforated prismatic, and perforated cylindrical cake powders. The limited appropriations available at the command of our Ordnance Department and want of a national powder-mill very much dwarfed his experiments, and delayed their prosecution to conclusive proof of their great value, a true estimate of which is found in the fact that they have now been more fully developed both in this and foreign countries, and led to the general adoption by all first-class powers of some such powders in their heavy ordnance; for example, Russia and Germany have adopted perforated prismatic cake powder; England, pellet, cubical, and pebble powders; the French, the powder of Wetteren and Bouchet; the Italian, the dice powder of the Fossano Mills near Turin; the United States, hexagonal, and has also experimented successfully with all the other varieties.

The great importance to be derived from increased and uniform density of powders as affecting their explosive qualities and consequent strain on guns, has at the same time attracted the general attention of those studying the subject.

Experiments are still in progress to determine the best description of gunpowders for all kinds of guns, whose employment in large charges shall be attended with the best results and the least risk of overstraining these guns.

Austria obtains her powder from government and private mills Italy, from Fossano.

HEXAGONAL POWDER.

Experiments were made at Fort Monroe in 1872 and 1873 with what is known as hexagonal-grained powder, manufactured by Messrs. E. I. Du Pont & Co., Wilmington, Del., which demonstrated its superiority for heavy ordnance, giving low maximum pressures, with good velocities and great uniformity of action. One of the samples, designated by the manufacturers as "E. V.," was selected for proof of the converted 8- and 9-inch rifled guns in 1874. Hexagonal powder has been employed since that date in trial and proof of all 8-inch converted guns. The uniform size of grain, and their polyhedral shape, insure great uniformity in position and size of the interstices in the make-up of the cartridge: this insures with a uniform density of grain a high degree of uniformity in pressures and velocities from given charges of powder and weights of projectiles. The powder used is composed of United States standard proportions of the ingredients, with a specific gravity of 1.7511. Its shape and dimensions are given on Plate IX.

The cartridge-bags were made allowing 0.85-inch windage; the material being woolen serge.

MANUFACTURE OF HEXAGONAL POWDER AT DU PONT'S POWDER-MILLS.

Plate IX.

The proportions of the ingredients of hexagonal powder conform to the United States standard, and up to the completion of the incorporation in the wheel mill, its manufacture is like that of ordinary powder.

Mealing.—The wheel mill cake is revolved in a cylinder of wire-wove cloth, with wooden balls, until it is mealed.

Pressing.—The mealed powder is then carefully pressed between horizontal metallic plates or dies. The powder comes out in a sheet or cake of polyhedral granules united along their vertical edges, the dies being nearly perfect dodecahedrons.

Graining.—The press-cake is passed between rollers armed with brass cutting teeth at an angle of from 60° and 120° to the axis, which cut the cake into granules, their cross-section being almost *hexagonal*, whence the powder derives its name.

Glazing.—The powder is then sent to the glazing-mill and glazed.

Brushing.—The powder is next passed repeatedly through the brushing-machine. This consists of a frame with brushes revolving near an inclined plane along which the powder passes by the motion of the brushes.

Drying.—The brushing ended, the powder goes to the dry-house where it is dried. The powder is now minutely examined, its specific gravity taken, and a count made of the granulation; a variation of two granules to the pound being enough to condemn the powder.

Rebrushing and redrying.—If satisfactory, the powder is again passed through the brushing-machine, redried, and then receives a third brushing.

Packing.—The powder is now packed in barrels and is ready for inspection.

PRISMATIC PERFORATED CAKE POWDER.

The adoption of this form of powder by some nations, and production of suitable machinery for its manufacture, necessitated the use of presses

of peculiar construction to insure sufficient and uniform density; the press (Plate VIII) to be so devised as to produce uniform size and shape of grains, and allow their ready withdrawal from the molds; the surfaces such as to allow close packing in a given space. These considerations led to the adoption of a regular geometrical figure; the hexagon offers a good shape for piling, the angles being all sufficiently obtuse to prevent breaking or spawling at the edges. Each layer and the whole cartridge is easily made up. Perforations were found necessary to insure better and more uniform control of combustion in the grain. The number of perforations first adopted were seven—one central, the other six at equal distances from the central one—although one perforation in the center has been found sufficient.

PREPARATION OF THE POWDER-BASE.

The ingredients for the manufacture of the powder-base are the same as used in manufacture of ordinary powder. The pulverized materials for 220 pounds are placed in a wooden drum lined with sole-leather, with 330 pounds of bronze balls, and subjected to 1,440 revolutions at the rate of 8 or 10 per minute. The powder is then brought to the moistening table of wood surrounded by an upright edge, over which is suspended a graduated glass measure having a copper pipe and rose at the bottom. On the table a charge of 55 pounds of powder is spread and moistened with 2¾ quarts of distilled water. It is then passed from a hopper to an endless canvas belt 20 inches wide, between a lower paper and upper bronze roller, weighing 2,425 pounds, making a revolution in twelve minutes. The bronze roller can be weighted to exert a pressure of 60,000 pounds. The powder is then broken into coarse lumps by wooden mallets, and granulated to two sizes of grains; the first, cannon powder—used for manufacture of the prisms—is passed through a sieve of 0.26 inch diameter of holes.

MANUFACTURE OF PERFORATED PRISMATIC POWDER.

Ordinary grain powder, made as above, is of a specific gravity of 1.5, and too elastic for use in the press. By reworking it loses a part of its elasticity, and is then fit for formation of the prisms by the following process: The powder-base, as above, is moistened with 10 per cent. of water, passed through the spindle press with the prescribed pressure and granulated grain and dust being collected in a receptacle. This mixture of grain and dust is dried in the air or by artificial heat till 1½ per cent. of the moisture remains. It is placed in a mixing-drum—220 pounds of powder and 330 pounds of bronze balls—and subjected to 1,440 revolutions, moistened and pressed as before, giving it a specific gravity of 1.675 to 1.75. It is granulated and separated, the cannon size again dried by air till 6 per cent. in dry weather of moisture remains, and placed in barrels covered with damp cloths for use.

FORMATION OF PRISMS.

The press for this purpose is constructed to give a pressure of 65,000 pounds per square inch. It consists of a heavy casting on a stone foundation; a main and secondary shaft, one fixed and two movable cross-heads. The main shaft carries a heavy wheel at each end, over which belts conduct the power from the center shafting to the press. It has a clutch operated by a lever for starting and stopping the machine;

two pinions on the main operate geared wheels on the secondary shaft, on which two eccentrics and cranks operate respectively, by connecting rods, the lower and upper movable cross-heads. These have each six hexagonal stamps perforated with seven holes, which enter corresponding hexagonal molds on the lower cross-head. Six groups of seven needles are fixed in such position that they extend up through the perforations of the lower stamps throughout into the molds and enter the perforations of the upper stamps as the latter descend to press the powder in the molds; these form the perforations in the prisms. The eccentrics and cranks operating the cross-heads are timed so that when the upper stamps have reached their lowest point of descent, the lower ones are moving upward giving the extreme pressure, after which the upper stamps ascend and the lower ones simultaneously push the perforated prisms up from the molds. The lower stamps constitute the bottom of the molds. The molds are filled from a hopper having a table with forward-and-back motion, containing six suitable measures which receive the powder from the hopper; the charging table moves forward and drops the charge in the molds; its edge carries the prisms brought up from the mold to an inclined shelf, whence they are removed. The capacity of the powder measures can be regulated as desired. Two rooms are required for each press; one for the press, the other for the prisms.

Before starting the press, the mold-needles and stamps and all rubbing surfaces ought to be oiled with a light pure oil or graphite.

All surplus lubricant must be wiped off. The powder to be pressed ought to have at least 5¾ per cent. of moisture. The moist prisms weigh about 620 grains each, and must not vary more than 5 grains. The first two sets of prisms should be rejected because of excess of oil. The weight of prisms must be verified. Three men can work a press; a carrier for every press is also required. The height and weight of the prisms must be verified from time to time, and the powder in the hopper stirred from time to time. Loose powder must be brushed away from the stamps and top of the molds; lubricate as often as once an hour. If a needle breaks, stop the press and replace it at once. On dry days, the powder loses moisture; this will be indicated by increased height of prisms or vibrations of the press, in which case moisten with ¼ per cent. of moisture, which is done in a drum by a fine rose sprinkler. The prisms pressed by the press contain about 5 per cent. of moisture, and must be dried to about ¾ per cent. by exposure to air or on shelves in a suitably arranged drying-room; they are then exposed to a temperature of 120° Fahr. for 48 hours, and are ready for packing.

The prisms are packed in wooden boxes in layers (12 rows of 11, and 11 rows of 9, 6 deep) weighing about 110 pounds to the box.

The prisms are regular hexagons 0″.992 high and 1″.6 width across the angles. The packing-boxes are of inch stuff, and may be tin-lined. Two sheets of felt—the smaller at one end, the other on top—keep the prisms from rubbing against each other in transportation.

The boxes have rope handles, and are marked with the weight, kind, place, and date of fabrication of the powder.

THE PELLET POWDER MACHINE.

Pellets are formed by compressing the powder meal into metal molds. Various shapes and sizes were tried; some were flat discs, others prisms, but the shape which found most favor at first was the cylindrical pellet ¾ inch in diameter by ½ inch in length, and weighing 9.5 grains. Origin-

ally these were made by hand, but it was soon apparent, that, if required in large quantities, machinery would have to be devised for their production; consequently a large machine of somewhat novel description, and capable of making 400 pellets at one time, was designed by Dr. John Anderson, and manufactured at Birmingham. This machine (Plate V, Figs. 11 and 12) is worked entirely by means of hydraulic power derived from an accumulator, which affords a pressure equal to 1,000 pounds per square inch. The machine consists of two hydraulic cylinders, with a division in the center of each, thus, in reality, making four cylinders; in the two upper ones a plain cylindrical ram is fitted, which merely rises and falls as the water is admitted underneath the ram or is withdrawn. These rams are used, first, for compressing the pellets, and second, for ejecting them, when finished, out of the mold plates. The two lower divisions are fitted with piston rams, securely attached to cross-heads, which are united together, and also connected to two other cross-heads above the cylinders by means of strong wrought-iron side rods, provided with collars working between lugs cast upon the hydraulic presses, and so adjusted as to allow only a certain limited travel either up or down. The upper cross-heads can be adjusted to their exact positions by means of screwed threads and lock nuts on the upper end of the side rods. The use of the lower piston rams is to close the upper openings in the mold plates by bringing the top punches, which are connected to the upper cross-heads by a gun-metal plate, down upon the mold plate, and thus confine the meal powder in the molds. The upper rams are now slowly raised, and these, acting upon the lower punches, compress the powder in the mold plate. After the proper density has been secured, the action of the lower rams is reversed, by which means both the lower and upper cross-heads receive an upward motion, thereby raising the upper punches clear out of the way, so as to admit of the compressed pellets being ejected out of the mold plate, and this is done by giving a further upward motion to the two plain cylindrical rams. This will be better understood by referring to the enlarged view (Fig. 12), where the mold plate, which is double, may be supposed to contain a charge of meal powder in the mold ready for compressing into a pellet. The lower part of the mold is closed by the lower steel punch that fits the mold very accurately, while the point of the punch rests upon the top surface of the plain cylindrical ram in the upper part of the hydraulic cylinder. The upper punch is also of steel, but much larger in diameter than the lower one.

To compress the powder in the mold and form a pellet requires four distinct movements of the machine. Frst, the upper punch is brought down until it rests upon the mold plate and closes the mold; this is effected by a downward motion of the two lower piston-rams, to which the upper and lower cross-heads are connected together with the upper punches. Secondly, the lower punches are raised by the two upper plain rams, and the powder is compressed in the mold between the two punches. Thirdly, when the pellet is sufficiently compressed, the upper punches are raised from off the mold-plate, this being done by reversing the action of the two lower piston-rams until the upper cross-head and punches are at a sufficient height to admit of the compressed pellet being ejected out of the mold plate. This fourth and last operation of ejecting the pellet is effected by allowing the upper plain rams to rise still further, and thus force the finished pellet out of the mold by means of the lower steel punches.

All these operations are simply and readily performed by means of a very ingenious arrangement of valves, the attendant having nothing to

do beyond placing a handle in the several positions indicated on a dial. These valves are so constructed that the water-power is admitted to the two presses simultaneously, whilst, by a self-acting arrangement, the pressure is shut off by the press itself when it has traveled the required distance. A relief valve is also provided to allow any excessive pressure to escape should it accumulate from any cause, and this prevents damage happening either to the pipes or other parts of the apparatus.

It is seen that a machine of this description is capable of making pellets of almost any shape, such as cylindrical, hexagonal, prismatic, or—what is possibly the best of all—spherical, by merely altering the form of the mold and punches. In the machine referred to there are (on a revolving table, the framework of which is made of gun-metal), four mold plates fitted; each contains 200 holes, but as there are only two hydraulic presses to the machine it follows that only two sets, or 400 molds, are under compression at one time, so that if we number these mold plates consecutively, then Nos. 1 and 3 will be under pressure whilst Nos. 2 and 4 are being filled. When the powder in Nos. 1 and 3 mold plate is sufficiently compressed, and the pellets formed therein have been removed, the entire table is turned one-fourth of the way round by means of a handle and a toothed pinion working into corresponding teeth provided round the periphery of the gun-metal table, the revolving of which is much assisted by eight small anti-friction rollers fixed to the cast-iron frame of the machine; these rollers support the gun-metal table as it revolves upon its own center. Nos. 2 and 4 mold plates, which have been wholly filled with meal powder, are now brought under the cross-heads of the machine and are in position for the powder contained therein to be compressed into pellets, whilst Nos. 1 and 3 in turn take their places to be refilled; the operation, therefore, of pressing and refilling are continuous, and the machine is capable of producing a large quantity of pebble powder per day and with very little waste.

THE PEBBLE-POWDER MACHINE.

Since the pebble powder was first brought into use, another description of large-grain powder, called "pebble powder," has been introduced for service with guns of large caliber. This pebble powder is formed of large grains ranging from eleven sixteenths of an inch to as much as 2-inch cubes; to manufacture this class of powder expeditiously and cheaply, has brought forth another description of machine for forming the pebbles by cutting up previously compressed cakes into cubes of the required dimensions. This is done in the following manner:

The cake as brought from the press-house is of the thickness of the required cubes; this cake the machine has to cut up—first, into long strips of the same width as the thickness of the cake; and, secondly, to cut these long strips transversely into cubes. This is accomplished in the machine by means of two pairs of rollers in the following manner: The cake is fed to a hopper immediately above the first pair of rollers, provided with knives upon their surfaces to cut the cake into long strips. The strips fall on an endless traveling band, which conveys and carries them to the second pair of rollers where they are cut transversely into cubes. They then drop into a spout, and are delivered to a revolving sifter covered with copper wire, which conveys the cubes to a number of wooden boxes contained in a small gun-metal truck; the dust and small pieces fall through the sifter into other boxes, and are taken back to the press-house and worked up again.

The framing of this machine (Plate VI, Fig. 13) is composed entirely of gun-metal, and has the requisite seatings cast upon it for the reception of the several brackets and pedestals, which are also of gun-metal, as well as the cutting rollers, each pair being about 7 inches in diameter, with a number of equidistant teeth formed upon their surfaces out of the solid metal.

These rollers are securely fixed upon wrought-iron shafts, which receive their motion from a main driving shaft by spur gearing. The under sides of the bearings of these rollers are planed and faced so as to slide in their respective brackets. One of each pair of bearings is fitted with a spring box controlled by a set screw, by means of which the amount of resistance to the opening of the rollers is adjusted. Blocks of hard wood are also fitted between each pair of bearings to act as stops, and thus determine the minimum distance between the surface of the rollers, and an adjustable gun-metal scraper is fitted to each roller for removing the surplus powder from its surface.

A skeleton carrying band, made of two leather belts fitted with ash cross-bars of a triangular section and at about 3 inches apart, is provided. These wooden cross-bars are riveted with copper rivets to the leather belts and to gun-metal strips upon their under side, these strips being of such a form as to serve the purpose of teeth for driving the band. This endless band works upon two gun-metal drums; the one is driven by gearing from the main shaft, and the other is fitted in adjustable bearings, which can be tightened by means of a screw so as to take up any slack. These drums are made with flanges at each end, and have recesses formed on their barrels to receive the gun-metal projections.

A sliding table made of hard wood and provided with four gun-metal grooved wheels, which travel upon V rails, also of gun-metal, is fitted to work underneath the carrying band, and travels at a uniform rate of speed. The top surface of this table is covered with leather, and made perfectly smooth; a reciprocating motion is given to it by means of an endless chain of sheet copper, upon one link of which a stud is fitted and works in a gun-metal block that slides in a bracket fixed upon the under side of the table. A weighted gun-metal frame is also provided, and so adjusted that the under side of it rests upon the upper surface of the bars of the carrying band; the ends of this frame are fitted with gun-metal stay-rods which project and work in slotted brackets connected to the machine; the frame is by this means free to rise if the pressure from any cause exceeds that of the weights by which it is held down. The under side of the frame is planed and made perfectly smooth, so as to allow the carrying band to work freely between its under side and the upper side of the sliding table.

The feeding web, which is made of strong Dowlas canvas, is driven by a gun-metal drum 7 inches in diameter, the following roller being $1\frac{1}{4}$ inches in diameter; the top surface of this web is supported by a board to prevent its sagging, and, in addition, the bearings wherein the shaft of the driving drum revolves are provided with slides made adjustable by means of screw-gearing.

A revolving sifter is fitted underneath the second pair of rollers, and works in bearings bolted to the under side of the framing of the machine; this sifter is composed of a number of gun-metal drums keyed upon a shaft, and its periphery is covered with copper wire, the whole being inclosed in a wooden casing. Underneath the sifter three sliding boxes are placed to receive the dust and small pieces which pass through the copper wire covering of the screen. At the end of the sifter a gun-metal traveling truck or carriage is provided, with four wheels adapted to run

upon V gun-metal rails fixed upon the floor. This carriage is capable of holding five wooden boxes, each about 18 inches square, into which the finished pebbles fall from the end of the sifter as it slowly revolves. A wooden hopper of sufficient width to cover the entire length of the roller is provided for feeding the press cake into the first pair, and a sheet-copper casing is fitted to the second pair, with a spout at the bottom for conveying the pebbles into the sifter.

All exposed parts, such as the ends of wrought-iron shafts, &c., are covered with recessed gun-metal washers securely fixed to them, and any others which may be made of iron or steel are covered with leather. All bearings are fitted with suitable lubricators, and channels or pipes for conveniently and efficiently lubricating the rubbing surfaces; and, as it is of the utmost importance that no oil or greasebe permitted to come in contact with the powder, the bearings of the cutting rollers are fitted with sheet copper casings made in halves and hinged, so that the upper part can be lifted and the bearings cleaned. The copper casings at the geared end of the rollers are sufficiently large to contain the wheels and act as drip-pans.

The pebbles from this machine, as well as the pellets from the hydraulic apparatus, are generally taken to the glazing barrels to glaze them and round off the sharp corners.

WIENER POWDER.

Colonel Wiener, of the Russian artillery, has patented a process of making gunpowder, claimed to be superior, and its manufacture safer, simpler, cheaper, and more expeditious, than that made by the ordinary process; its peculiarity is the exclusion of water and substitution of heat to 240° Fahr., in forming press-cake. The cake is broken into grains as usual; the powder is free from dust; it absorbs less moisture, and is said to have greater and more uniform force. The saving is estimated at 40 per cent. Samples were shown in the Russian exhibit at the Centennial exhibition at Philidelphia.

ITALIAN "PROGRESSIVE POWDER"

Is made of grain powder of various sizes, from 0.1 to 0.6 inch, and "farina" or meal powder, mixed in proportions of 1 and 2 of grain to 1 of meal. This mixture is pressed into cakes of various thickness and broken up into irregular grains—resembling our mammoth powder, and cubes from 1 to 2 inches on a side—(the pressure reduces the mass to about two-thirds of its thickness, or say 1.75 specific gravity.) The irregular grains and cubes make up the charge.

GUN-COTTON.

This comparatively new and powerful explosive has not, as yet, obtained favor in military circles, on account of its supposed want of stability. Recent experiments and investigation tend to show that this supposition is not warranted, if the gun-cotton is properly prepared. Its manufacture should be intrusted to competent and responsible parties only, and conducted with the greatest care and circumspection. A factory has been established at Waltham Abbey, under the immediate supervision of officers.

In all the various stages of manufacture, the gun-cotton is, in a wet state, entirely harmless, and its manipulation unattended with danger.

Special buildings and precautions are therefore not required in its manufacture; brick buildings and steam motors are available.

Long staple, high quality, raw cotton is the best. Waste cuttings, such as is used for cleaning machinery, is preferred, for the reason that it has been thoroughly cleaned. The waste must be free from impurities, such as seed-husks and foreign substances, and dry. It is first picked over by hand, and then passed through a machine with toothed rollers, which open and loosen the cotton, and subject it to a strong blast to blow off foreign matters.

To remove moisture absorbed at ordinary temperatures, it is subjected to a temperature of 126° for 20 minutes in a drying room, heated by air in contact with coils of hot pipes; ventilation carrying off the moisture.

The cotton is fed by a trough to endless belts, with a slow motion, carrying it from one belt to another, and leaving it in a close closet. When thoroughly dry, it is weighed out in parcels of about one pound, and stored in a cool place, in closed tin boxes.

The acid used must be highly concentrated and of uniform specific gravity; the nitric 1.52 and the sulphuric 1.85. The acids are thoroughly mixed in the proportion of three sulphuric to one of nitric, by weight, first placed in separate tanks, provided with pipes or outlets and brought together in a single pipe, in which a mixer moves by a pulley on the outside. After mixing, the acids are forced into tanks well covered and allowed to cool to the temperature of the atmosphere.

The cotton being immersed in the acids, the nitric acid acts on the cotton, and this, with the liberated water, causes considerable heat, which must be regulated and controlled. For this purpose the vessels in which the cotton and acids are placed are surrounded by cold water. The tanks—14 inches wide, 2½ feet long, and 16 inches deep, filled with the proper measure of acids—are placed in troughs, through which a constant flow of water is kept; into these tanks the one-pound charges of cotton are dipped. Each workman is charged with three consecutive tanks; he receives the charges for these, plunges the first into a tank and leaves it, then plunges a charge into the second and third tanks. By this time the charge in the first tank, having been exposed sufficiently long to the action of the acids, is taken out with an iron fork and laid on a grating, where the acid is removed as far as can be by using the fork as a lever. The charge is then placed in an earthen jar, covered, and deposited in the soaking room for 24 hours in a basin of water. The cotton absorbs about eleven times its weight of acids. The workman replaces this amount with fresh acids in the tanks, puts in a new charge, and proceeds to the second tank, going through the same operation as above, and so on.

During the 24 hours' experience in the soaking room the greatest care must be taken that no water comes in contact with the cotton, as it would cause the ignition and entire combustion of the cotton. If such an accident occurs, strong fumes of nitrous acid are evolved, and the jars must be removed to the open air at once.

The next operation is to get rid of the free acid in the cotton, which is done by a centrifugal drying-machine, 30 inches in diameter, making 1,500 revolutions per minute. The machine receives the contents of six jars, uniformly distributed, before setting it in motion. When the acid ceases to drop from the cotton, it is taken out and the remaining acid removed by washings in fresh water. Large tubs, provided with wooden wheels, are used, small portions of the cotton being plunged and submerged at once to prevent its ignition. It is then dried in a centrifugal

machine, again washed and dried, and then reduced to pulp in an ordinary pulping machine.

The pulp is then run into a poaching machine, where it is repeatedly washed in fresh water, and finally in water slightly alkaline. This operation is continued until the cotton will sustain a severe heat test, and requires from 48 to 100 hours; and before being taken from the poaching machine is washed in slightly alkaline water of carbonate of lime and soda.

The gun-cotton, now complete as far as its explosive quality and resistance to change are concerned, should retain 3 per cent. of the alkalies. The greatest care must be taken that none of the details of manufacture are slighted.

To control the explosive power of gun-cotton, the pulp is compressed into homogeneous masses of required form and density. For mining and torpedoes, it is pressed into disks 3 inches in diameter and 1.75 inches thick, of a density a little greater than water at 60° Fahr. (between 1 and 1.003). Each disk has two holes, 0.2, inch, bored through it, and weighs about 9 ounces.

A pressure of 15 tons is required, provision being made in the press for the escape of water. The disks are packed in water-tight boxes. After filling the boxes, water is poured in and allowed to remain some minutes, after which the water is poured out and the boxes securely covered. It may then be kept, without fear of accident, indefinitely.

Wet gun-cotton may be exploded by use of a small portion of dry cotton and a detonating fuse.

The factory at Waltham Abbey has a capacity of 4,000 pounds per day; and the cost per pound is 42½ cents.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1. Charcoal grinding mill.
Fig. 2. Saltpeter and sulphur grinding mill.
Fig. 3. " " charcoal and sulphur sifting reel.

Fig. 4.

Fig. 5.

Fig. 4. Mixing machine.
Fig. 5. Incorporating machine.

Fig. 6.

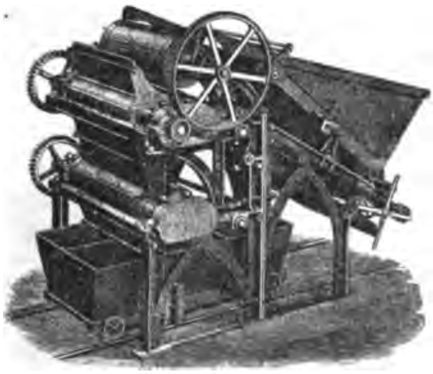


Fig. 7.

Fig. 6. Breaking down machine.
Fig. 7. Hydraulic press apparatus.

Fig. 8.

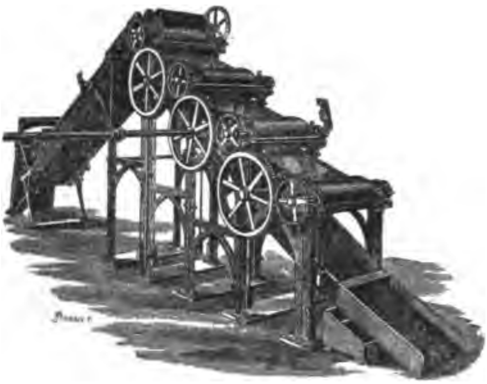


Fig. 9.

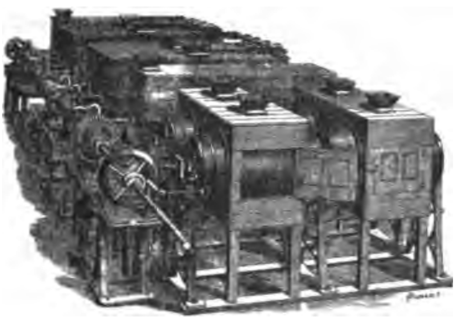


Fig. 8. Granulating machine.
Fig. 9. Dusting reels and glazing barrels.

Fig. 10.

Fig. 11.

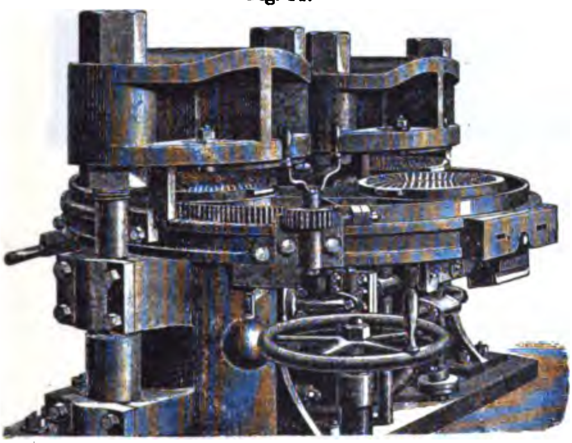


Fig. 12.

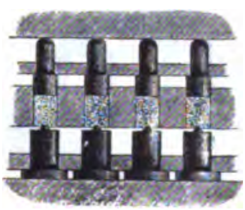


Fig. 10. Drying stove.
Fig. 11. Pellet powder machine.
Fig. 12. " " "

Fig. 13.

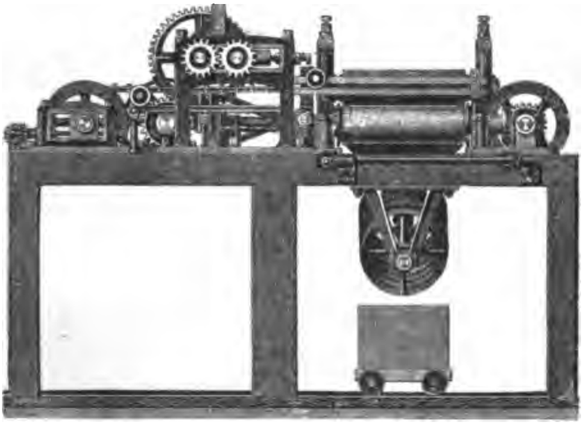
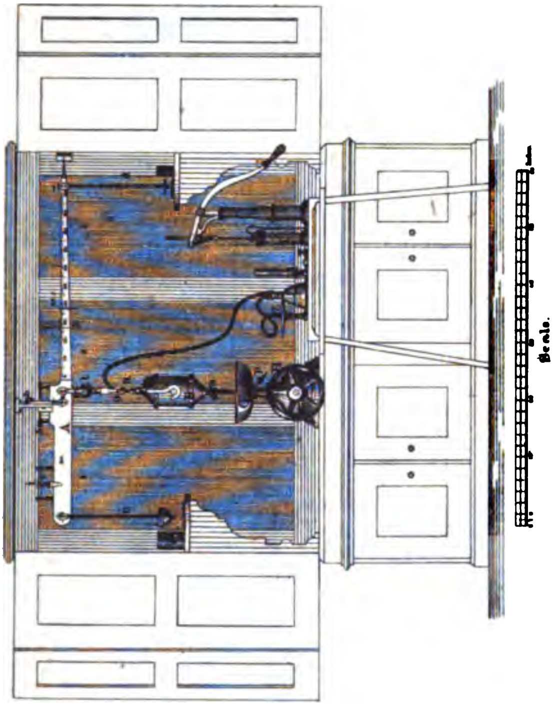


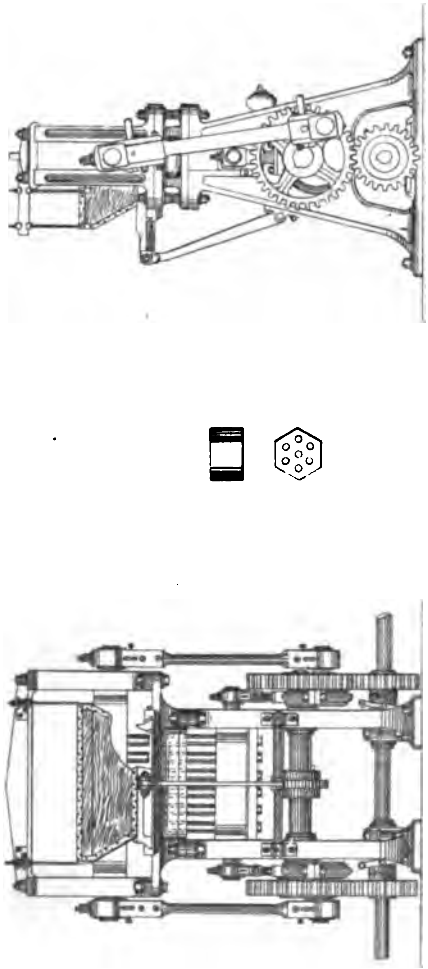
Fig. 14.

Fig. 13. Pebble powder machine.
Fig. 14. Mercury densimeter.

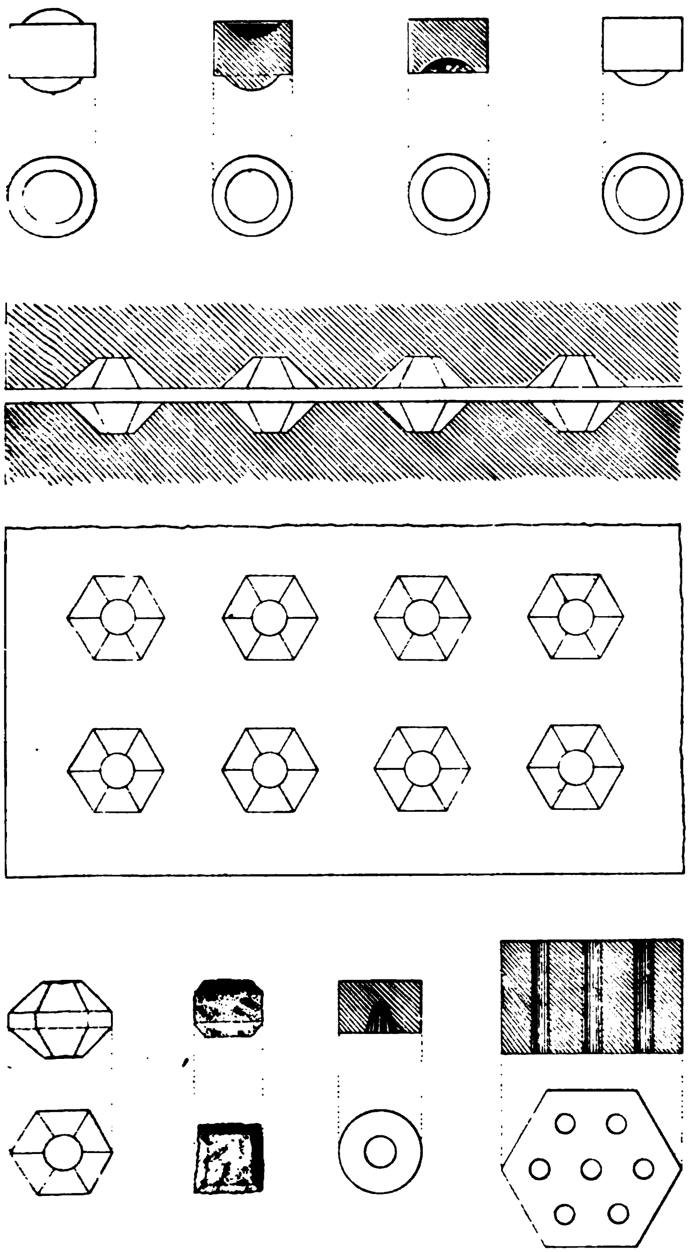
Densimeter for large grain powder.



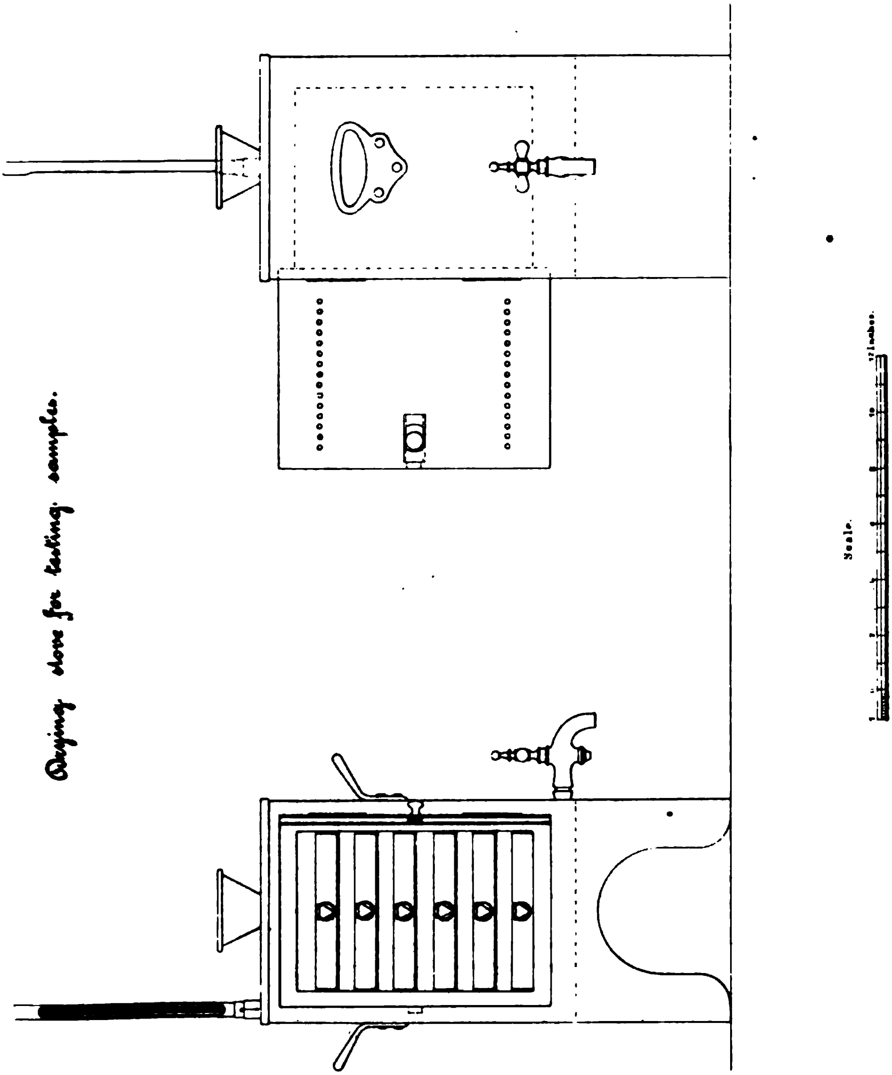
Press for perforated prismatic cake powder.



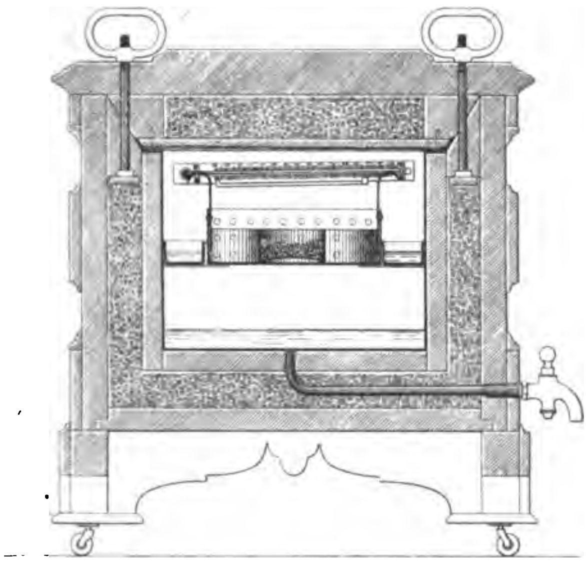
Forms of large grained powder.

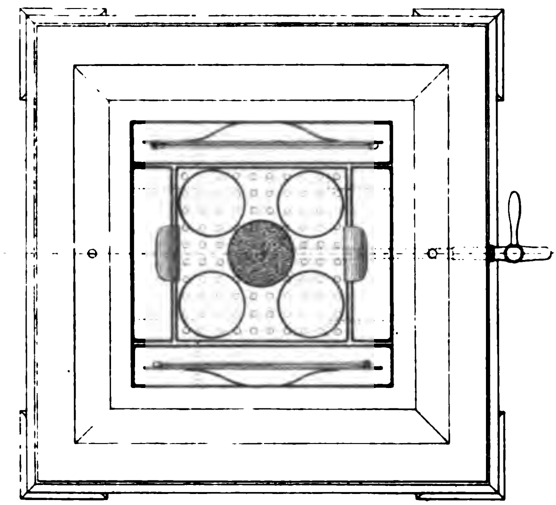


Drying stove for testing samples.



Hygroscope.

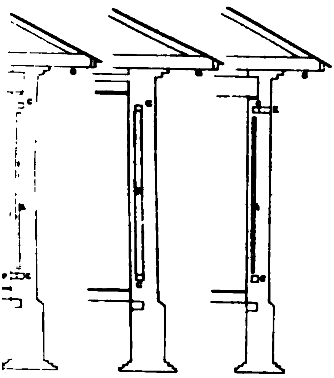




Appendix I.—Report of Chief of Ordnance, 1879.

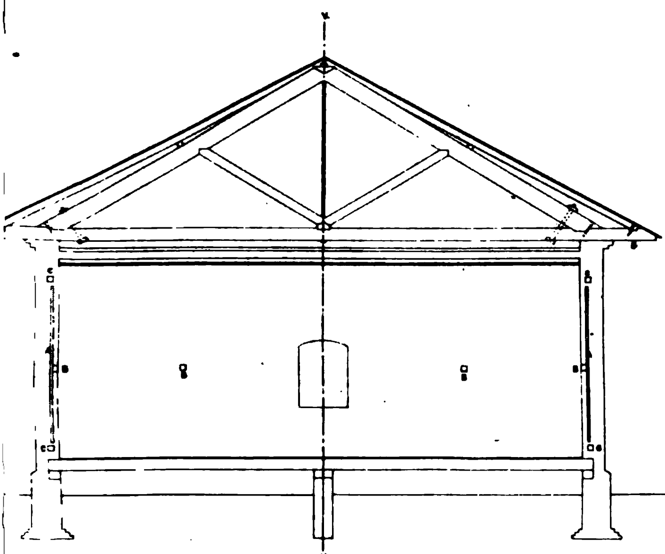
Scale

R MAGAZINE.



ION THROUGH Y.Y. | SECTION THROUGH Z.Z. | SECTION THROUGH U.U.

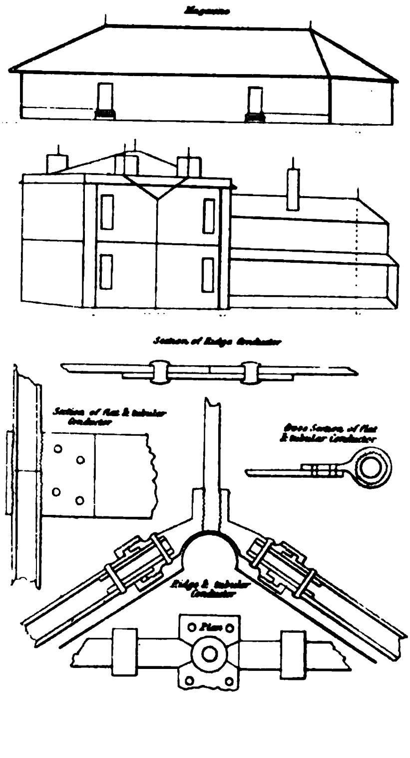
A Air chambers
B Communication between air chambers and interior of magazine.
C Air passages
D Communication between upper and lower air passages
E Communication between upper air passage and exterior atmosphere
F Communication between lower air passage and interior of magazine
G Lower surface of projection of roof to be sealed with tin, painted on both sides, and perforated with small holes to allow free circulation of air under the roof.



SECTION THROUGH M.M.

Lightning rods for magazines.

'IGHTNING RODS



INDEX.

APPENDIX I[1].

PROGRESS REPORT ON POWDERS FOR 4.5-INCH RIFLE.

With the view of determining the proper charge and kind of powder for use in the 4½-inch rifle, the Board has from time to time tested samples of powders furnished by the Messrs. Du Pont. It has been the desire of the Board to get a powder which, using *about* 7-pound charges, with shot weighing 35 pounds, shall give a muzzle velocity of about 1,600 feet per second, with a corresponding pressure of not exceeding 35,000 to 40,000 pounds per square inch of bore.

An examination of the accompanying summary of results obtained shows that the H. D. No. 1 and No. 2 gave entirely too low velocities; the H. D. No. 3, good velocities and pressures, but not as good as H. D. No. 4, which, with 7 pounds of powder and 25-pound shot, gave an average velocity of 1,578 feet per second, with a corresponding pressure of 27,750 pounds per square inch of bore; the same charge of powder and 35-pound shot gave 1,411 feet velocity and 31,250 pounds pressure. The H. D. No. 5 gave good velocities, but the pressures were entirely too high; the same may be said of the H. M., H. N., and H. O. samples.

The H. Y. and H. V. powders gave excellent results with charges below 6 pounds, but with this and a higher charge the pressure increased rapidly. The H. V. powder was specially made to test the effect of reducing the diameter of the cartridge, thereby increasing the initial burning space. Two rounds, each of 4.5 and 6 pound charges, were fired on the 30th of April, 1879, that the resulting pressures and velocities might be ascertained and compared with those obtained with other powders. The results with this powder, using the ordinary sized cartridge bag, were very satisfactory. Those using reduced bags, while showing that, with the same charge, the velocities and pressures *generally* diminished as the windage increased, are too meager for any satisfactory deductions.

It is thought the Messrs. Du Pont will be able to improve even upon the best results so far obtained; the Board therefore propose to continue these experiments. So far the H. D. No. 4 powder has given the best results.

AVERAGES.—*Experiments to ascertain proper kind and charge of powder for use in 4½″ siege rifle.*

Number of rounds.	Date.	Powder.				Projectile.		Elevation.	Instrumental velocity.	Pressure per square inch of bore.	Remarks.
		Kind.	Density.	Granulation.	Weight of charge.	Kind.	Weight.				
					Lbs.		*Lbs.*	*Deg.*	*Feet.*	*Lbs.*	
1	May 12, 1877	H. D. No. 1	1.78	360	3½	Abesterdam raised in weight by filling with sand.	23½	—½	713	Less than 10,000	
1	...do	...do	"	"	4		25½	—½	765	"	
1	May 26, 1877	H. D. No. 2	"	630	3½		25	—1	773	"	
1	...do	...do	"	"	4		25	—1	912	"	
1	...do	H. D. No. 3	1.778	1,250	3½		25	—1	865	"	
1	...do	...do	"	"	4		25	—1	1,028	"	
2	Nov. 15, 1878	...do	"	"	5		25	0	1,193	6,250	
2	...do	...do	"	"	6		25	0	1,368	12,000	
2	...do	...do	"	"	7		25	0	1,518	21,500	
2	...do	...do	"	"	7½		25	0	1,530	36,000	
2	May 26, 1877	H. D. No. 4	1.776	3,038	3½		25	—1	945	Less than 10,000	
1	...do	...do	"	"	4		25	—1	1,123	10,000	
2	Nov. 16, 1878	...do	"	"	5		25	0	1,306	12,500	
2	...do	...do	"	"	5½		25	0	1,359	15,500	
2	...do	...do	"	"	6		25	0	1,436	22,750	
2	...do	...do	"	"	7		25	0	1,578	27,750	
2	Nov. 26, 1878	...do	"	"	7		35	0	1,411	31,250	
1	May 26, 1877	H. D. No. 5	1.78	7,795	3½		25	—1	1,118	10,000	
1	...do	...do	"	"	4		25	—1	1,238	26,500	
1	...do	...do	"	"	5		25	—1	1,398	61,500	
1	Sept. 12, 1878	H. M. No. 1	1.755	1,550	3½		25	0	1,277	27,000	
1	...do	...do	"	"	4		25	0	1,405	26,000	
1	...do	...do	"	"	4½		25	0	1,498	50,000	
1	...do	H. M. No. 2	"	"	3½		25	0	1,281	20,500	
1	...do	...do	"	"	4		25	0	1,333	26,500	
1	...do	...do	"	"	4½		25	0	1,510	60,000	
1	...do	H. M. No. 3	"	"	3½		25	0	1,301	26,000	
1	...do	...do	"	"	4		25	0	1,397	28,500	
1	...do	...do	"	"	4½		25	0	1,467	120,000	Estimated; cut too long to accurately measure.
1	...do	H. N. No. 1	1.607	22,930	3½		25	0	1,405	60,000	
1	...do	H. O. No. 1	1.757	23,012	3½		25	0	1,362	39,500	
6	Apr. 10, 16, '79	H. Y.	1.772	3,000	5		25	0	1,372	25,000	Supposed to be like H. D. No. 4.
3	...do	...do	"	"	5½		25	0	1,412	20,500	
3	...do	...do	"	"	6		25	0	1,521	45,333	
2	Apr. 30, 1879	H. U.	1.778	950	4		25	0	1,124	8,750	Intended to test sub-caliber cartridges (cartridges of reduced diameter).
2	...do	...do	"	"	5		25	0	1,259	11,500	
2	...do	...do	"	"	7		25	0	1,505	26,750	
2	...do	H. V.	"	1,250	4		25	0	1,162	9,750	Intended to duplicate H. D. No. 3.
2	...do	...do	"	"	5		25	0	1,307	15,750	
2	...do	...do	"	"	7		25	0	1,538	43,250	

The following trials were made, in addition to the above, to test the effect of reducing the diameter of the cartridge-bag.

Number of rounds.	Date.	Powder.				Projectile.		Elevation.	Instrumental velocity.	Pressure per square inch of bore.	Dimensions of cartridge.			
		Kind.	Density.	Granulation.	Weight of charge.	Kind.	Weight.				Circumference.	Diameter.	Windage.	Circumference after filling with powder and shaking down.
					Lbs.		*Lbs.*	*Deg.*	*Feet.*	*Lbs.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
4	May 29, 1879	H. U	1.778	950	7	Absterdam raised in weight by filling with sand.	25	−¼	1,489	26,750	12.9	4.10	0.4	....
2	do	do	"	"	7		25	−¼	1,472	28,000	12.6	4.01	0.49	13.00
2	do	do	"	"	7½		25	−¼	1,505	42,000	12.6	4.01	0.49	13.00
1	do	do	"	"	7		25	−¼	1,441	23,500	12.2	3.88	0.62	12.70
1	do	do	"	"	7½		25	−¼	1,491	30,000	12.2	3.88	0.62	12.70
2	do	do	"	"	8		25	−¼	1,494	37,000	12.2	3.88	0.62	12.70
1	do	do	"	"	7		25	−¼	1,433	17,500	11.9	3.78	0.72	12.5
1	do	do	"	"	7½		25	−¼	1,496	28,000	11.9	3.78	0.72	12.5
2	do	do	"	"	8		25	−¼	1,528	27,000	11.9	3.78	0.72	12.5
1	do	do	"	"	7		25	−¼	1,345	12,000	11.0	3.50	1.00	11.5
1	do	do	"	"	8		25	−¼	1,422	13,500	11.0	3.50	1.00	11.5
1	do	do	"	"	9		25	−¼	1,523	26,000	11.0	3.50	1.00	11.5
1	do	do	"	"	10		25	−¼	1,510	17,000	11.0	3.50	1.00	11.5
1	do	do	"	"	7½		25	−¼	1,225	8,500	(*)	(*)	(*)	(*)

*Experimental.

APPENDIX I[2].

PROGRESS REPORT ON POWDERS FOR 8-INCH RIFLE.

The powders tested in the 8-inch converted breech-loading rifle were Du Pont's hexagonal F. P. B. powder, density 1.785, granulation 67; Du Pont's hexagonal G. H., the same density and granulation as F. P. B., and intended to be a duplicate of it; and finally Du Pont's hexagonal E. V. J., density 1.750, and granulation 72. The G. H. powder, it will be seen from the record, did not give as good results as the F. P. B., and this inferiority did not result from any great difference in the age of the powders, nor from any difference in the seasons of the year when fired. It probably arose from some unavoidable difference in the manufacture or some variable atmospheric conditions.

The E. V. J. gave better results than either of the others, as far as velocities are concerned, for the same charge, but the pressures are somewhat higher, though hardly enough to be considered dangerous. It is probable, however, that better results will be obtained both with F. P. B. and G. H. by increasing the charge of powder, but as this gun has to be tested for endurance, it was deemed advisable to keep the charge to what has heretofore been considered standard.

The same powders were also fired from some of the 8-inch muzzle-loading converted guns, and the same remarks will apply as to the results obtained. The other powders tried were Oriental hexagonal; Du Pont's hexagonal H. P., H. Q., and E. V. L., and Laflin & Rand's polyhedral, but none of them gave as good results, except the E. V. L., which is a duplicate of E. V. J.

Results obtained with experimental and other powders from 8" rifles, since last reports.

BREECH-LOADING

No. of rounds.	Date of firing.	Powder. Kind.	Granulation.	Density.	Weight charge.	Butler projectile.	Velocity at 110 feet.	Pressure per square inch of bore.	Remarks.
					Pounds.	Pounds.	Feet.	Pounds.	
1	Aug. 1 and 17, 1878	Du Pont's hexagonal F. P. B	67	1.785	15	185	....	8,600	Gun fired to date 202 times.
2			67	1.785	20	185	....	17,250	
1			67	1.785	25	184	....	25,600	
2			67	1.785	25	185	....	18,500	
2	Aug. 2 and 8 and Dec. 5, 1878		67	1.785	30	183	....	23,000	
1			67	1.785	30	185	1,220	22,000	
1			67	1.785	30	186	1,331	29,500	
1	Oct. 17, 1878		67	1.785	35	175	1,303	23,500	
2	Oct. 17, 1878, and June 11, 1879		67	1.785	35	178	1,306	24,500	
4	May 23 and 27 and June 11, 1879		67	1.785	35	179	1,342	25,000	
8	Oct. 25, 1878, May 9, 13, and 21 and June 11, 1879.		67	1.785	35	180	1,339	26,750	
11	Oct. 17 and 25, 1878, May 8, 9, and 27 and June 11, 1879.		67	1.785	35	181	1,347	27,122	
29	Aug. 22 and 23, Nov. 1, 1878, and May 8, 9, 13, 21, 23, 27, 28, 1879.		67	1.785	35	182	1,350	26,200	
8	Aug. 22, Dec. 5, 1878, and May 9, 21, 23, 28, 1879.		67	1.785	35	183	1,342	26,188	
9	Aug. 8, 9, Oct. 18, 1878, and May 21, 1879.		67	1.785	35	184	1,319	26,777	
7	Aug. 2, 8, and 9, 1878		67	1.785	35	185	1,313	25,428	
7	Aug. 8 and 17, 1878		67	1.785	35	186	1,336	27,643	
2	June 6 and 10, 1879	Du Pont's hexagonal G. H	67	1.785	35	178	1,321	28,000	
7			67	1.785	35	180	1,312	24,800	
14			67	1.785	35	182	1,293	25,833	
5			67	1.785	35	183	1,264	24,000	
1	June 11, 1879	Du Pont's hexagonal E. Y. J	72	1.750	30	180	1,272	27,000	
5	June 18 and 21, July 9 and Aug. 15, 1879		72	1.750	35	175	1,423	34,750	
5	June 11 and 21, 1879		72	1.750	35	177	1,411	36,500	
12	June 11, 18, and 21 and July 9, 1879		72	1.750	35	178	1,423	37,250	
24	June 11, 18, and 21, July 9 and 11, and Aug. 13, 15, and 27, 1879.		72	1.750	35	180	1,397	36,500	
14	June 18 and Aug. 13, 14, and 15, 1879		72	1.750	35	181	1,393	38,700	
3	June 18 and July 11, 1879		72	1.750	35	182	1,405	40,166	
2	June 18 and Aug. 13, 1879		72	1.750	35	183	1,394	38,500	
1	July 9, 1879		72	1.750	35	185	1,388	35,500	

Results obtained with experimental and other powders from 8′ rifles, since last reports—Continued.

MUZZLE-LOADING.

No. of rounds.	Date of firing.	Powder. Kind.	Powder. Granulation.	Powder. Density.	Powder. Weight charge.	Butler projectile.	Velocity at 110 feet.	Pressure per square inch of bore.	Remarks.
					Pounds.	*Pounds.*	*Feet.*	*Pounds.*	
6	Sept. 12, 13, and 26 and Oct. 10 and 11, 1878.	Du Pont's hexagonal E. V. J ...	72	1.75	35	180	1,454	40,250	8″ No. 1. Gun fired to date 817 times.
1			72	1.75	35	181	1,468	41,500	
1			72	1.75	35	182	1,433	37,500	
1			72	1.75	35	183	1,456	40,000	
1	May 24, Aug. 2, and Oct. 4, 1878	Du Pont's hexagonal F. P. B ...	67	1.785	35	182	1,353	27,500	
3			67	1.785	35	183	1,367	30,833	
2			67	1.785	35	185	1,358	26,200	
1	Sept. 20, 1878	Oriental hexagonal (brown charcoal).	....	....	30	181	1,234	33,000	
1			....	....	30	182	1,249	34,500	
1			....	....	35	181	1,319	60,000	
1	Sept. 21, 1878	Du Pont's hexagonal H. P	....	....	30	181	1,388	45,500	
1	Sept. 21, 1878	Du Pont's hexagonal H. Q	....	....	30	182	1,374	36,500	
1			....	....	30	181	1,385	37,000	
1			....	....	35	177	1,461	44,000	
2	Sept. 21, 1878	Laflin & Rand's polyhedral	....	....	30	182	1,288	32,500	
5			....	....	35	180	1,360	37,500	
2	Feb. 20, 1879	Du Pont's hexagonal F. P. B	67	1.785	35	180	1,258	23,100	8″ No. 5. Gun fired to date 639 times.
3	May 28, 1879	Du Pont's hexagonal E. V. L ...	72	1.75	35	180	1,428	37,500	8″ No. 38. Gun fired to date 183 times.
1			72	1.75	35	181	1,417	39,000	
2			72	1.75	35	182	1,404	36,500	
1			72	1.75	35	183	1,416	40,000	
1	June 26, 1879	Du Pont's hexagonal E. V. J ...	72	1.75	35	181	1,407	25,500	
2			72	1.75	35	180	1,396	38,250	

APPENDIX I³.

PROGRESS REPORT ON 3.5-INCH "DEANE" BRONZE GUN.

(One plate.)

This gun, fully described in the Report of the Chief of Ordnance for 1877, page 653, has been fired in all to date 50 times.

Three different powders have been so far used in the test: "Mortar," granulation 77,350; "Mortar E. Z.," granulation 25,888; and "Mortar E. Z. A.," granulation 31,232. Three different weights of projectiles have also been fired: shells empty; shells loaded with sand equal in weight to weight of bursting charge; and solid shot; weighing respectively 15, 15½, and 16¾ pounds, but all of the Butler pattern.

A summary of the results and the star-gauge record are appended.

The gun has so far stood the test for endurance satisfactorily; the greatest enlargement was at 54″ from the muzzle, and only 0″.017.

The bore remains smooth and perfect, no sensible erosions having occurred.

Summary of results of firings at Sandy Hook, N. J., with Dean's 3.5-inch bronze rifle.

AVERAGES.

Dates of firing.	Number of rounds.	Powder.		Projectile.		Pressures.	Velocity.
		Kind.	Charge.	Kind.	Weight.		
			Pounds.		*Pounds.*		
September 1, 1878	2	Mortar	2½	Shell filled with sand.	15½	28, 250	1, 264
September 1, 1878	2	Mortar	2½	Solid shot	16¾	28, 000	1, 229
September 1 and May 1, 1879.	5	Mortar	3	Solid shot	16¾	44, 400	1, 311
September 1, 1878*	10	Mortar	3	Solid shot	16¾	....	....
May 1, 1879	3	E. Z	3	Solid shot	16¾	29, 000	1, 186
May 1, 1879	7	E. Z	3	Shell	15	25, 429	1, 255
May 1, 1879	5	E. Z. A	3	Solid shot	16¾	22, 600	1, 227
May 1, 1879	16	E. Z. A	3	Shell	15	20, 500	1, 273
Total	50						

* Fired at mile target. Target plottings appended; 3 sighting shots.

Table of enlargements of 3½-inch Deane bronze gun.

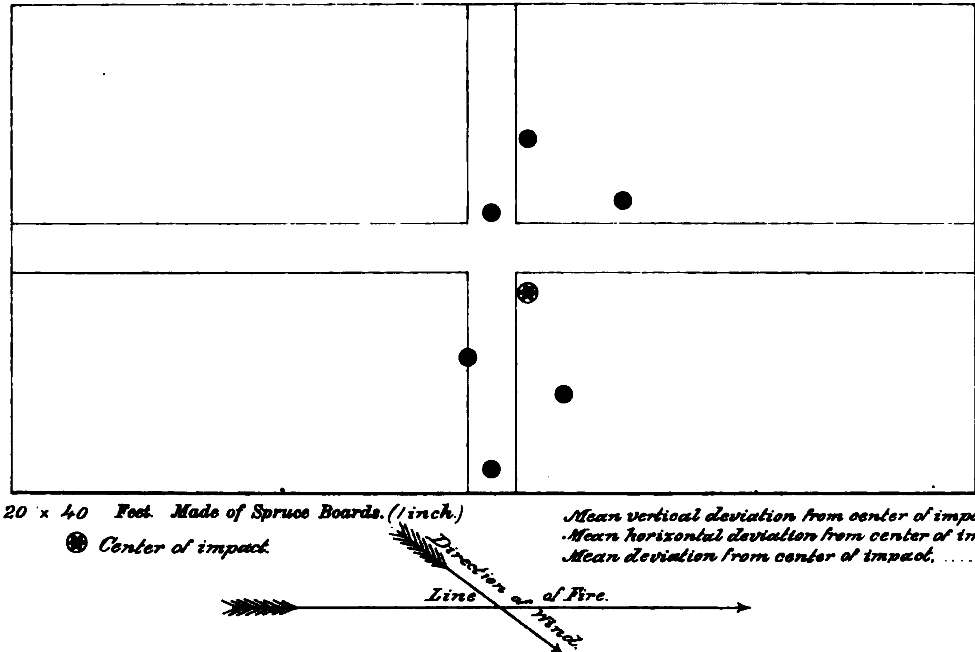
Inches from muzzle.	Original diameter of bore.	Enlargement of bore, after—			
		A total of 16 rounds.	A total of 26 rounds.	A total of 36 rounds.	A total of 50 rounds.
58¼	3.504	0.006	0.009	0.010	0.012
58	.504	.006	.009	.010	.012
57¾	.504	.005	.010	.010	.012
57½	.504	.005	.010	.011	.011
57¼	.503	.006	.012	.012	.013
57	.503	.006	.011	.012	.013
56¾	.503	.007	.012	.012	.013
56½	.503	.007	.013	.013	.013
56¼	.503	.007	.013	.013	.013
56	.504	.007	.012	.012	.014
55¾	.504	.008	.013	.013	.014
55½	.505	.007	.012	.013	.014
55¼	.505	.008	.013	.013	.014
55	.505	.008	.014	.014	.015
54¾	.505	.009	.014	.014	.015
54½	.505	.010	.014	.015	.016
54¼	.505	.010	.015	.015	.016
54	.505	.010	.015	.015	.017
53¾	.505	.009	.015	.015	.016
53½	.505	.009	.016	.016	.016
53¼	.505	.010	.015	.015	.016
53	.505	.010	.015	.015	.016
52¾	.505	.010	.015	.015	.016
52½	.505	.010	.014	.015	.015
52¼	.505	.009	.014	.014	.015
52	.505	.008	.014	.014	.014
51¾	.505	.007	.012	.013	.014
51½	.505	.007	.012	.012	.013
51¼	.505	.005	.011	.012	.013
51	.505	.005	.011	.011	.012
50¾	.505	.003	.010	.010	.011
50½	.505	.003	.010	.010	.011
50¼	.505	.003	.009	.010	.010
50	.505	.002	.009	.009	.010
49¾	.505	.001	.008	.009	.010
49½	.505	.001	.008	.008	.010
49¼	.505	.001	.008	.008	.010
49	.505	.001	.008	.008	.010
48	.505	.001	.008	.008	.009
47	.506	.000	.007	.007	.009
46	.506	.000	.007	.007	.009
45	.506	.000	.007	.008	.009
44	.506	.000	.007	.008	.009
43	.506	.000	.007	.008	.009
42	.506	.000	.007	.008	.009
41	.506	.000	.007	.008	.009
40	.506	.000	.007	.008	.009
37	.506	.000	.007	.009	.009
34	.507	.000	.007	.008	.008
31	.508	.000	.006	.006	.007
28	.510	.000	.005	.005	.006
25	.512	.000	.003	.003	.004
22	.513	.000	.002	.003	.005
19	.514	.000	.004	.004	.006
16	.514	.000	.004	.004	.006
13	.514	.000	.006	.006	.006
10	.514	.000	.006	.006	.007
7	.514	.000	.006	.006	.007
4	.513	.000	.007	.007	.008
1	.513	.000	.009	.009	.010

TARGET RECORD OF 3½ INCH DEANE BRONZE M. L. RIFLE.

At Sandy Hook, N J., Sept. 27th, 1878.

Target One Mile from Gun.

Number of Rounds Fired, 7. *Number of Hits in Target, 6.*



Target 20 x 40 Feet. Made of Spruce Boards. (1 inch.)

Center of impact.

Mean vertical deviation from center of impact, ... 4.67 feet.
Mean horizontal deviation from center of impact, ... 1.83 "
Mean deviation from center of impact, ... 4.93 "

APPENDIX I[4].

HOTCHKISS REVOLVING CANNON, CALIBER, 1.5 INCHES.

(Seventeen plates.)

TRIALS IN 1876 AND 1877.

A description of the Hotchkiss revolving cannon.

THE GENERAL SYSTEM.

The Hotchkiss revolving cannon cannot be classed with mitrailleuses in the ordinary sense of the latter term, as explosive shells are fired with the former, and it has a range equal to that of field-artillery.

The system of this gun may be explained as follows:

Five barrels, grouped around a common axis, are revolved in front of a solid breech-block, which has in one part an opening to introduce the cartridges, and another opening through which to extract the empty shells, while the cartridges are fired after being revolved and while motionless in front of the solid portion of the breech.

The exterior aspect of this revolving cannon resembles the Gatling mitrailleuse, it being, on the other hand, entirely different in its interior mechanism.

The system is composed of two distinct parts, viz, the barrels with their disks and shaft, and the frame and breech containing the mechanism.

The five barrels, made of the finest oil-tempered cast-steel, are mounted around a common axis, between two disks, on a central shaft. The series of barrels are in this way placed in a rectangular frame, which is attached to the breech, the near end of the shaft penetrating the same to receive the rotary motion from the driving-gear.

The breech itself is composed of a solid cast-iron breech-block, weighing about 386 pounds. This absorbs the greater part of the recoil. It has a door at the rear end, which can be easily opened, so that the mechanism is freely accessible, and can, if necessary, be dismounted and put back into its place in a few minutes without the aid of any special tools.

A peculiar feature of this gun consists in the barrels remaining *still* during the discharge, so that there is no movement of any kind to impede the accuracy of the fire. This stop or lost motion is obtained by the shape of the driving-worm, which is so constructed that the inclined driving-thread only covers half its circumference, the other half of the thread being straight. The effect of this is that the barrels only revolve during half a revolution of the worm, and stand still during the other half revolution. The combination of the mechanism is so arranged that the loading, firing, and extracting takes place during this pause. This feature is of great importance for the accuracy of fire and the durability of the system.

The worm-shaft projects through the breech on the right side, and has a crank with which the whole system is moved; on the left side of the

worm-shaft a small crank is attached, by which the loading and extraction of the cartridge-shells are effected in the following manner:

On the interior face of the left side of the breech a cog-wheel is mounted, with two horizontal racks, the one being placed above the other under this cog-wheel, and parallel to the axis of the barrels, so that in moving one of these racks the other is moved by the cog-wheel in the opposite direction. Part of the lower rack forms a vertical slot, in which the small crank on the left side of the worm-shaft works. The rotation of the latter consequently gives an alternating and opposite movement to the two racks, so that while the one is going forward the other moves back, and reciprocally.

The under rack forms the extractor; the upper one moves a piston which drives the cartridge into the barrels, the cartridge being placed before the piston, in the trough in which it moves; and during the time the barrels are motionless it is introduced into the one standing before the trough. The cartridge is not "driven home" entirely, but its head is in view of an inclined plane, cut into the metal of the breech, on which it slides when it is moved by the rotation of the barrels. This completes the introduction of the cartridge into its chamber. The piston itself is a simple cylinder connected with the rack and running in a slot in the conducting-trough.

When the racks are in their extreme positions they remain still a moment. This stop is obtained by giving the slot in its center part a circular shape concentrically to the shaft of the crank. This is necessary, because at the moment of the barrels arriving at the end of their course the head of the cartridge-case becomes engaged in the hooks of the extractor, which would not be possible if it were in motion at the time.

The extractor is a large double hook at the end of the bottom rack; it is very solid, and its proper working is certain under all circumstances.

After the cartridge is extracted from the barrel it strikes against an ejector, which pushes it out of the extractor, and it falls to the ground through an opening in the under part of the breech. The firing-pin has an elongation, pointing downward, which, by the operation of a spring, is pressed against a cam on the worm, and as the worm rotates the cam drives the firing-pin back and compresses the spring. The moment the firing-pin becomes liberated it strikes the primer of the cartridge and the discharge takes place.

To obviate the difficulties which exist in other systems, when the cartridges are piled one upon the other, the opening of the introduction-trough is closed by a little door, which goes down by the weight of the cartridges, the first of which drops into the trough, and then the piston, in moving forward, raises the door and allows no more cartridges to enter until the proper time.

All parts of the mechanism are very strong and durable, and hardly exceed in number those of an ordinary small-arm, there being, besides the group of barrels, thirteen parts, viz:

1, 2. The breech-block, with its door for closing the rear end.

3, 4, 5. The crank-shaft, with its worm for moving the barrels, and small crank for working the loader and extractor.

6. The crank.

7, 8. The firing-pin and spiral spring.

9. The extractor.

10, 11. The loading-piston and rack for moving it.

12. The cog-wheel for transmitting the movement of the extractor to the loading-piston.

13. The door for regulating the feed of cartridges.

The operation of the mechanism, the rapidity of fire, and the number of men to work the gun.

The operation of the mechanism may be described as follows, supposing the crank to be in continual motion:

A cartridge is placed in the introduction-trough, the piston pushes it into the barrel, then the barrels begin to revolve, and the cartridge is carried on till it arrives before the firing-pin, which penetrates the solid part of the breech, and which has in the mean time been retracted by the action of the cam. Then, as soon as the cartridge has arrived into this position, the barrels cease to revolve, and the primer of the cartridge is struck by the firing-pin and discharged; then the revolution of the barrels begins again, and the fired cartridge-shell is carried on until it comes to the extractor; this, in the mean time, has arrived up to the barrels and the cartridge-head rolls into it. As soon as the head is laid hold of by the extractor the barrels again cease to revolve, and during this period the cartridge-shell is withdrawn and dropped to the ground. As during every stoppage of the barrels the gun is supplied with a new cartridge, and the firing and extraction is also performed, during this time a continuous but slow fire is kept up. By supplying the gun in this manner with single cartridges, about thirty rounds per minute may be fired.

Should rapid firing be required, the gun is then supplied, not with single cartridges, but with "feed-cases," containing groups of ten cartridges each, and in this manner from sixty to eighty rounds per minute can be fired, with only three men to work the gun, viz, one man to train the gun and revolve the crank; one man to place the "feed-cases" containing the cartridges into the "feed-trough"; and a third man at the ammunition-chest to charge the "feed-cases," and to hand them to the charger.

Attached to the frame is a turn-table which connects the cannon to the "trunnion-saddle," arranged in such manner that without displacing the carriage a certain amount of lateral motion as well as of elevation may be given to the gun. Thus the gun is made to sweep horizontally along a line, by adjustment, between each single shot or during rapid discharge.

THE AMMUNITION.

The ammunition for the revolving cannon consists of a center-fire metallic cartridge of special construction, holding in each one the powder, the projectile, and the lubricating-wad, arranged like the similar ammunition generally used for small-arms.

Two different kinds of projectiles are used, the one an explosive shell and the other a case-shot. Nothing need be said of the latter, as it does not differ from the common case or canister shot used in ordinary cannon.

THE SHELL.

The shell is of a novel construction; it is of cast iron, of a cylindro-ogival shape, slightly rounded at the rear end. The packing consists of a brass coat of about one caliber in length, and placed equidistantly from the center of gravity. This coat is of soft brass tubing, contracted with great pressure over the body of the projectile, it being provided with longitudinal grooves, and two grooves encircling it at the top and bottom ends of the packing. The coating is forced into these grooves, and any disturbance of it on the body at starting is thus obviated. These grooves serve at the same time as breaking-lines of the shell.

After the coating is attached to the projectile some small saw-tooth-like grooves are cut into it, to reduce the strain while being forced through the rifling of the barrel. These grooves can be filled with a lubricating substance, and this is then carried perfectly between the projectile and the bore of the barrel.

The coating of the projectile is conical at its front part, corresponding with the cone in the projectile-chamber, so that it is exactly centered in the bore as soon as the forward movement commences. Its rear end is cylindrical to within about one-third of its length.

The shell is turned smooth all over, and is nearly 0''.016 in diameter less than the bore of the barrel. This projectile is made with great care and exactness, with only a very small deviation in dimension.

THE FUSE.

The fuse employed is that known as the Hotchkiss percussion-fuse, used in large quantities during the last war in America.

It consists of a gun-metal body closed at the front end with a nose-screw, forming the ogival point of the projectile; it has a conical hole at the rear, which is closed with a lead plug (the safety-plug), pressed in very tightly, so that the plug projects a little through the base of the body-case toward the inside.

The plunger is composed of lead, cast into a brass casing to strengthen it and to prevent the lead from being upset by the shock of discharge. A brass wire is cast into the lead of the plunger and holds it suspended in the case, the wire going through the hole in the bottom of the case and being held securely in position by the safety-plug. The plunger has a nipple cast into the lead, and is formed with an ordinary gun-cap; in its axis it has a powder-chamber containing the igniting-charge.

The operation of the fuse is thus: The safety-plug is dislodged backward into the interior of the projectile by the shock of discharge; the wire then being not held tight in the hole, the plunger is disengaged and rests on the bottom of the fuse-case, and is free to move in the line of axis. When the flight of the projectile is suddenly retarded by its striking any object, the plunger, in consequence of its inertia, is driven forward, and the primer strikes against the nose-screw, thus igniting the powder in the channel, and so firing the bursting-charge of the projectile.

The Hotchkiss percussion-fuse is extremely simple in its construction, and requires no adjustment before use. It is perfectly safe in transport, and during all manipulations with the projectile, as the plunger is held securely by the safety-plug, which must receive the great shock of the discharge to discharge it from its hole and thus liberate the plunger.

THE CARTRIDGE-CASE.

The cartridge-case consists of a spirally-rolled tube of sheet-brass, strengthened at the head with an inside and an outside cup. The head is punched out of sheet-iron, and is fastened to the cups with three rivets.

The primer consists of a case holding the anvil, and is closed at the bottom end by the cap containing fulminate. It is fitted into a hole which penetrates the head and both cups, and it projects through into the inside of the cartridge-case.

This cartridge, which can be manufactured with great facility on account of its simplicity, has proved itself to be of a very durable quality, and it can be used repeatedly.

The construction of the body of the cartridge allows it to expand to the chamber of the gun without the metal being stretched, so that after the discharge it contracts itself again to its previous diameter, thus leaving the fired case perfectly loose in the chamber for extraction.

THE LUBRICATOR.

The lubricator consists of a wad of felt about 0''.236 thick, dipped in a solution of mixed tallow and beeswax. A paper disk is placed between the lubricating-wad and the charge to prevent the powder getting damaged by the greasy surface of the lubricator.

The projectile is merely pressed into the neck of the cartridge and is not clinched, as there is enough friction to hold it absolutely secure.

Of course the ammunition is, as in the case of all modern small-arm ammunition, which it resembles, rendered safe against influences of weather and danger of explosion.

Principal dimensions and weights, &c., of the gun.

Caliber	1.457	inches.
Total length of bore	4 feet 2.236	inches.
Length of rifling	3 feet 8.882	inches.
Rifling, one turn in	4 feet 1.212	inches.
(Twist and depth of grooves uniform.)		
Number of grooves	12	
Width of lands	0.098	inch.
Depth of grooves	0.019	inch.
Number of barrels	5	
Diameter of barrel over powder-chamber	3.464	inches.
Diameter of barrel at the muzzle	2.440	inches.
Weight of each barrel	77.166	pounds.
Radius of sights	2' 3''.047	
Vertical distance of the line of sight from the common axis of the barrels	2.0366	inches.
Horizontal distance of the line of sight from the common axis of the barrels	6.496	inches.
Weight of gun	1,047.25	pounds.
Total weight of gun with traversing apparatus	1,157.48	pounds.

Principal dimensions and weights of the ammunition.

EXPLOSIVE SHELL.

Length of body	4.10	inches.
Entire length with fuse	4.71	inches.
Length of brass coating, equidistant from center of gravity	1.5	inches.
Diameter of body	1.44	inches.
Diameter of brass coating	1.49	inches.
Weight of body of the projectile	1 pound 1.4	ounces.
Weight of fuse	3.3	ounces.
Weight of bursting-charge *	0.74	ounce.
Total weight of projectile complete for firing	1 pound 5.58	ounces.

Weights and dimensions taken from shell fired by the board.

CASE-SHOT.

Length of case	4.565	inches.
Exterior diameter of case	1.440	inches.
Number of balls	18	
Diameter of each ball	0.62	inch.
Average weight of each ball	1.03	ounces.
Total weight of shot	1 pound 9.4	ounces.

*It would be advisable to use either gun-cotton or picrate powder for the bursting-charge, as these would throw the fragments forward with more force than ordinary gunpowder and thus produce a greater destructive effect.

CARTRIDGE-CASE.

Length of cartridge-case	4.724	inches.
Diameter of head	1.791	inches.
Diameter of the body near the head	1.641	inches.
Diameter of body in front	1.476	inches.
Weight of cartridge-case	3.88	ounces.

CHARGE OF POWDER.

Charge	4.23	ounces.
Proportion of charge to weight of projectile	4.33	
Weight of complete cartridge	1 pound 10.46	ounces.
Length of complete cartridge	8.149	inches.

THE CARRIAGE.

For the revolving cannon a special carriage has been constructed. This was found necessary, as the ordinary field-gun carriage is not provided with the means for procuring an excellent and immovable rest for this gun.

The trail of the carriage consists of two brackets of steel plate, connected by three transoms and bolts, the rear end being connected by the trail eye-piece. The brackets diverge against the trunnions.

The trunnion bearings and the bearings for the axle-tree are riveted to the outside of the brackets, and are fitted in the ordinary manner.

The axle-tree is of steel, the arms being slightly conical. The wheels have metallic naves and ring-tires. The nave consists of two parts—the inside flange, with the pipe-box, and the outside flange. The spokes are cut in a conical form at their "hub" ends so that they fill the nave-flanges, and the two parts of the nave are bolted together with the spokes with six screws.

These wheels are very strong, and have been found practical and economical in service, and they allow spokes to be easily substituted for others when broken.

The elevating arrangement consists of a screw working in a gun-metal nut resting in the oscillating bearing. This nut is revolved by conical gear-wheels from the left side of the trail, the top end of the screw being attached to the trunnion saddle-plate.

The handspike is hinged to the trail so as to fold back in traveling. A tool-box is placed between the trail; this at the same time makes a solid connection of the trail-brackets.

The carriage of the revolving cannon is usually provided with a light steel shield for the protection of the gunners from small-arms fire.

This shield is of three parts, made to fold together, thus forming seats for two men. It can immediately, when coming into action, be unfolded, and only the muzzles of the barrels and the wheels of the carriage are exposed to the enemy. The steel plates are about 0.236 inch in thickness.

Two boxes are attached to the axle-tree, each to carry three feed-cases loaded with ten rounds of ammunition.

On the carriages not provided with a shield these ammunition-boxes are protected by light steel plates in front, and have a lid of steel, which, when raised, forms a small protecting shield, and when closed they form seats for two gunners, so that with two or three gunners on the limber a sufficient number of men to serve the piece would be taken into action with the gun itself.

To check the recoil of the gun, a brake of the following construction is used:

Each axle-arm has a screw cut on its extremity; this carries a nut

forming a conical cap, partly enveloping the front side of the wheel-nave, which is likewise conical to fit the inside of the cap; this has a short crank, by which it can be revolved on the axle. When screwed up this cap grips the cone of the nave of the wheel, and the tighter the cap is screwed up, so the wheel turns with the more difficulty on its axis, until it gets immovably locked on the axle by the friction of the cones. When the cap is unscrewed it is disengaged from the wheel, which can then turn freely on the axle. The screws on the ends of the axle-arms have right and left handed threads, so that the caps become tightened, by the effect of the recoil.

This brake is used at the same time as an ordinary traveling-brake, and it can be applied without the carriage being stopped, as is necessary with the shoe-brake commonly used on gun-carriages.

Principal dimensions and weights of the carriage.

Weight of carriage, with wheels, ammunition-boxes, and accessories, complete	1,169 pounds.
Weight of steel shield	331 pounds.
Weight of wheels, each	187 pounds.
Diameter of wheels	55 inches.
Weight of trail on the ground	99 pounds.
Weight of trail when hooked on limber-hook	44 pounds.
Track of wheels	59 inches.
Angle of trail with the ground	17° 30′
Height of trunnions above the ground	42 inches.
Extreme angles of elevation and depression	—5°+25°
Greatest angle of dispersion with horizontal training apparatus	3°

THE LIMBER AND THE AMMUNITION-CHEST.

The limber resembles, in general construction, the French government service-limber; it consists of a frame-work of wood, placed upon wheels of equal size and construction as those of the gun-carriage.

The axle-tree is of steel; it has no axle-tree bed, but is attached directly to the "futchells."

The trail of the gun-carriage hooks up to a hook-pintle attached to the axle-tree. The limber has a swing splinter-bar to which the traces of the horses are attached, and the shaft is arranged for double-draught.

The limber carries an ammunition-chest made of wood, conveying four hundred rounds of ammunition, and it is fitted with four boxes, each containing one hundred rounds. The cartridges are held immovably in the boxes when the lids are closed, to prevent their being injured in traveling over rough roads. The ammunition-chest is covered with painted sail-cloth and is rendered water-tight; the corners are protected by angle-irons, and it is attached to the limber by two hooks and screws.

The weight of the limber, with ammunition-chest complete, is 661 pounds.

Summary of principal weights.

	Pounds.
Gun, with lateral-training apparatus	1,213
Carriage, with all accessories	926
Limber, with ammunition-chest	661
Four hundred and sixty rounds of ammunition	761
Four gunners	529
Total	4,090

This weight distributed over six horses gives 680 pounds per horse, a very low rate, the usual weight for the draught of a horse in light-artillery being about 771 pounds; so that this gun possesses that which in

modern warfare is so necessary—the quality of easy transportability to a satisfactory extent.*

Since the publication of the above, Mr. Hotchkiss has made a slight improvement in his shell, which has been satisfactorily tried by the Board.

The improved Hotchkiss shell is with its fuse a little less than three calibers in length, or about seven-sixteenths inch shorter than the one just described, from which it differs, with the above exception, in the following particulars only: The new shell has four circumferential grooves separated by ribs about one-twentieth inch wide, and longitudinal cuts between ribs. The tubing, about one caliber in length and one-sixteenth of an inch thick, instead of being corrugated on the exterior, as in the old shell, is perfectly smooth, and is contracted into place by a *slight* pressure only. The gas from the discharge presses the packing so firmly into the grooves and cuts that it cannot rotate independently of the projectile, and the rifling is impressed on the ribs only covered by the tubing.

Its dimensions and weights are as follows:

Length of body	3.66 inches.
Entire length with fuse	4.27 inches.
Length of brass coating	1.5 inches.
Diameter of body	1.44 inches.
Diameter of brass coating	1.49 inches.
Weight of body of the projectile	1 pound 1.4 ounces.
Weight of fuse	3.3 ounces.
Weight of bursting-charge	0.88 ounce.
Total weight of projectile complete for firing	1 pound 5.58 ounces.

RESULTS OF FIRING AT SANDY HOOK, NEW YORK HARBOR.

On the 11th of September, 1876, the preliminary trial of the gun took place, Mr. Hotchkiss being present.

Forty rounds were fired with new mortar-powder, testing the working of the gun. On the 12th and 22d, same month, the gun was fired for *initial velocities*, the average of three rounds new mortar-powder giving 1,294 feet; of 12 rounds, musket, 1,572 feet; and of 18 rounds, old mortar, 1,458 feet. September 21 and 22, 72 rounds were fired at a target 1,000 yards distant, and 51 rounds at a 2,000-yard target, not including sighting-shots. (See targets marked A and B, plates V and VI, appended.) September 22, 4 rounds of shell and 26 of canister were fired at a 200-yard target. The working of the canister not being very effective, no further trials were made with it at even these short ranges, the shell, everything considered, being deemed more satisfactory than canister. On the 3d of October the gun was again fired 72 rounds, testing its working. Up to this time 309 rounds in all had been fired.

A supply of 3,000 rounds of ammunition having been procured, the Board resumed its experiments November 23, 1876, and concluded them February 15, 1877.

November 23, 1876, 115 rounds were fired at target 2,000 yards distant, and the time taken of firing 20 and 51 shots; and on the 24th of November, 15 rounds were fired at targets 2,640 yards distant, but owing to high winds the firing was suspended and targets not tabulated.

On the 2d of December, 143 rounds were fired at 1,000-yard targets, not including 7 sighting-shots. (See targets marked C, plate VII, ap-

* The foregoing description of gun, shells, &c., was taken from the pamphlet of Mr. Alfred Koener, published in Paris, 1874. The French measures have been transferred into our own for convenience of reference.

pended.) One hundred and seventy rounds were fired at 2,000-yard targets, not including 4 sighting-shots. (See targets marked D, plate VIII, appended.)

On January 25, 1877, 102 rounds were fired at 10 targets, the first being 200 yards distant; and on same date 100 rounds were fired at 2 targets, the first the same distance from gun. (See targets marked E and F, plates IX and X, appended.)

On February 14, 1877, 44 rounds were fired at targets 200 yards distant, and on the 15th 100 rounds were fired at targets 1,000 yards distant, not including 12 sighting-shots. (See targets marked G and H, plates XI and XII appended.)

This makes a record of 1,136 rounds in all fired, and throughout the firing the gun worked well. There were four failures in the ammunition during the early part of the firing, owing to the weakness of the firing-pin spring, but after this spring was changed no failures occurred.

The fuses, with one exception, worked perfectly; on examining this fuse after firing, it was discovered that the fuse-firing pin on nose-screw was broken, which would readily account for the failure to explode.

The cartridge-cases, of wrapped metal, worked well, extracted easily, and no gas escaped. The loader and extractor worked easily and well, as did the mechanism generally. There was no wabbling, tumbling, or stripping of projectile, the brass coat or packing taking the grooves well in all cases. In fact, with the exception of the four miss-fires and one failure to explode, already explained, everything worked very satisfactory during the entire firing.

The special carriage for this cannon seems strong, compact, and serviceable, and possesses some novel features. The recoil-brake, which takes the place also of the ordinary shoe-brake, is secured to the axle-arm, and works by means of a short lever. This brake, and also the shield, which, when not in use, folds and forms seats for the cannoniers, have been fully described heretofore. There is also at the end and under side of trail a pointed, wedge-shaped piece of iron, which, being forced into the wooden platform or ground, prevents the trail from moving during firing.

ACCURACY AND EFFECT.

The targets were made of one-half inch and one-inch boards, and were constructed in sections, which enabled them to be rapidly erected and placed in their required position.

It will be seen (Record of Firing, appended) that they were grouped for the different ranges of 200, 1,000, and 2,000 yards, and that the sizes were such as to cover, generally, all cases of different army formations. All the useful effects of fire were thus recorded on them and its full value made apparent.

Results at 200 yards. Targets E, F, G, appended—Plates IX, X, and XI.

Three different series of targets were placed at 200 yards. At the first (10 targets, 52 feet by 6 feet, 50 feet apart) 102 shells were fired, giving 2,140 hits. At the second (2 targets, 52 feet by 11 feet, 75 feet apart) 100 shells were fired, giving 1,045 hits. At the third (2 targets, 26 feet by 6 feet, 75 feet apart) 44 shells were fired, giving 309 hits.

The destructive effects on the first series are apparent, giving about 1,600 hits per minute, and using only about 125 pounds of metal.

The other series also illustrate the destructive power of this weapon at short ranges, such as would be used in the service of our armament for the flank-defenses of our sea-coast fortifications.

Results at 1,000 *yards. Targets A and C, appended—Plates V and VII.*

Two targets (11 feet by 26 feet) were made at this distance, firing in the first case 72 rounds and in the second 143. The total number of hits was 1,597 for 215 projectiles in all fired. As the time of firing is about 80 rounds per minute, an analysis shows that a continuous and dangerous fire (about 590 hits per minute) can be secured at this range. A third series (target H, appended, plate XII), firing at 10 targets (52 feet by 6 feet, 50 feet apart, and representing a regiment in column) was made, using 100 shells; 1,626 hits were noted. This gives a continuous and dangerous fire of 1,300 hits per minute, and using only 125 pounds of metal—results not yet attained in any other machine-gun, nor with our present field-artillery. The range of 1,000 yards, however, is one too long for accurate effects, generally, from the lighter caliber of other machine systems (fired even with great deliberation).

Results at 2,000 *yards. Targets B and D—Plates VI and VIII.*

The targets made at this distance were accomplished by firing 221 rounds, and the total number of hits was 1,019; a continuous and dangerous fire, at this range, of 370 hits per minute.

Any comparison at this distance ceases with other machine-guns; and we have to consider the system at this range as a competitor of field-cannon.

No direct comparisons have been as yet made by the board between the Hotchkiss revolving cannon and the ordinary field-pieces, but it is thought well to allude in this connection to the more recent practice with the most approved field-artillery. The recent experiments in Austria are probably the best so far made, and will afford us a fair comparison. This comparison will be incomplete, but this incompleteness will favor the field-artillery rather than the Hotchkiss system.

The records alluded to show that 40 shells, "with double walls," weighing in the aggregate, say, 560 pounds, gave 1,497 hits on targets placed at 1,658 yards. The time required for accurate firing could not have been less than ten minutes. This amount of metal if delivered from the Hotchkiss revolving cannon would, if a ratio following from the results already quoted is accepted, give 2,000 hits, and at a distance of 2,000 yards, and in a time of seven minutes.

Comparison cannot be made at the maximum ranges (4,000 yards) reported by the Austrian artillery, as no records are yet made at this distance with the revolving cannon.

RESULTS IN FRANCE AND BRAZIL.

An inspection of the results of firing at Gavre will show that, at a range of nearly 2,000 yards, as favorable results as those given at Sandy Hook were attained; the rapidity of fire being the same, and the number of hits (354) in a record of 80 shots showing nearly the same percentage as our results at the above-mentioned range. The range and accuracy attained also show a capacity for effective fire up to about 5,500 yards.

The trials also at Gavre with the revolving cannon, French marine model, also gave strong confirmatory evidences of its superiority in range and accuracy, besides its effectiveness in other respects.

The results in Brazil are also highly favorable to the gun and the official opinions of its merits decided.

DISCUSSION OF THE SYSTEM.

The introduction of this gun has marked a new departure in that class of arms which next succeeds in power the personal weapons of the soldier; and it gives fair promise as a powerful auxiliary to our modern field systems and to our present contemplated armaments for the defense of the short flank-lines of our permanent works.

It is evident that, in the latter service, a long-range gun capable of securing an intense, accurate, continuous, and deadly fire at the short ranges ordinarily employed for this service, and having most of the advantages of the howitzer-fire, formerly fully, and now partially, relied upon for protecting our ditches and flank-lines under all ordinary circumstances of attack, must prove a highly desirable adjunct, if not a superior means of defense to the present systems employed; limited as they are in power, and consequently in range, and without superiority in rapidity and continuity of fire or in deadly effects.

Its range is at least 5,500 yards, which renders it equally as powerful as a shell-gun in this respect, and one capable of guarding the approaches to works, either permanent or field, at shell-gun distances, while at the same time being effective at ranges of 1,000 to 1,500 yards, the maximum distances ordinarily required to be covered by our flank-defense armaments.

Its power for delivering a continuous and uninterrupted effective fire at ranges indifferently from the shortest range required up to three miles, would seem to point to it or a similar system—employing the same general principles—as being a *necessity* for introduction in the future armament of our forts, and for service, when occasion demands, in our field-works.

In this connection, as germane to the question of flank-defense, the Board would call attention to the importance of the introduction into our service of a shell-gun of more accuracy, length of range, and destructiveness and rapidity of fire than the present 8-inch howitzer. This, it is believed, can be attained by a breech-loading rifle-howitzer of a caliber of 6 inches, throwing canister for short ranges as well as case-shot, and using the latter with percussion or concussion fuses; and for all ranges a special case-shot weighing 65 pounds, and containing bullets, 14 to the pound; also, canister of a weight of, say, 54 pounds, using 0.8-inch lead bullets, and a shell of 61 pounds.

The effects with these projectiles must be decidedly superior to those attainable with our present 8-inch-howitzer ammunition, and in order to perfect a flank-defense howitzer it is recommended that experiments in the direction indicated also be undertaken in connection with others now pending, looking to a proper armament of our flank-defenses.

REGARDING FIELD-SERVICES.

It is evident that this system gives promise of proving a valuable and powerful auxiliary to the light artillery of our service.

Its equality in range, its greater capacity for delivering a deadly, incessant, and widespread fire at all field-ranges, and with decidedly superior rapidity; its stability when fired, abolishing all but the ordinary initial pointings, and its evident superiority in pursuing retreating columns, give it some decided advantages, apparently, over our ordinary field-guns.

For the effects of artillery-fire, however, where penetration is desira-

ble, and where destructive effects of solid shot and shell in rapidly demolishing large objects, &c., are required, we must, of course, yield the advantage to the larger calibered field-pieces.

Its uses, however, as a powerful auxiliary to the service under consideration cannot be doubted from the above considerations; and the Board believes that its great efficiency as a field-piece, when tested, will probably be established.

RECOMMENDATIONS.

The results of the above-recorded tests of the Hotchkiss revolving cannon at Sandy Hook, and the records of the results obtained abroad, lead the Board to recommend further, more extended and exhaustive trials to fully determine its merits, with a view to its final adoption as an auxiliary arm, not only for flank defense but for other branches of the service. To further this end the Board recommends the procurement of at least 4 guns (the number to be governed by the state of the appropriation) of the model and caliber tested; and with a supply of ammunition not exceeding 2,000 rounds per gun, the carriages needed to be made at the Watervliet arsenal, after well-matured drawings to suit the nature of our service. Two of the guns procured to be placed in the field, to be reported upon after thorough trial, and two, with carriages adapted for flank-defense casement-service, to be placed in some of our casemated works for trial and tests. It further recommends that experiments be continued with the present gun at Sandy Hook.

Extract of the report of the trial of B. B. Hotchkiss revolver cannon, made by the French Government at Gavre.

GENERAL OBSERVATIONS.

The mechanism of the cannon revolver is simple, and substantially made.

The traverse apparatus is simple, and works satisfactorily.

The iron gun-carriage has worked well during all the trials.

The fuse is simple, without any danger for manipulation, and requires no preparations on the battle-field.

Ballistic properties.—The elevation for the maximum range is about 35°; range, 4,600^{m} (about 5,031 yards). The accuracy of the revolver cannon in horizontal deviations is remarkable, and very much superior to that of the mitrailleuse.

Obturations.—The gas-check produced by the cartridge has been constantly good. The system of the cartridge-case is a good one.

Working of mechanism.—The working of the firing-pin has been constantly good. The loader worked always well during all trials. The principle of the extractor is a good one. The traverse motion and the elevating-screw worked always well.

Working of the brass coats of projectiles.—The projectiles examined after firing showed the print of the bands on the coat very distinctly, and of the same width as the bands. The results show this principle of the brass packing to be a good one.

Time of salvos.—Mean time for ten shots, 11.6 seconds.

RESULTS OF FIRING. (EXTRACT OF REPORT.)

Firing against a battalion in columns by division at enti e distances. (Experiments of 27th February, 1873.)

The battalion is represented by 3 targets of 1.80 meters (about 6 feet) height and 70 meters (about 230 feet) width. The first at 1,650 meters (about 1,804 yards) from the cannon. The second at 1,720 meters (about 1,881 yards). The third at 1,790 meters (about 1,957 yards).

Powder-charge, 85 grammes; bursting-charge, 20 grammes; powder of Ripault.

Angle of fire, 6° 36′.

Two salvos of 40 shots fired, the first without traversing, the second with traversing.

The number of projectiles or pieces which, per hundred, reached the targets are, for the revolver cannon, 70.

In comparing this result with those obtained by the Gatling mitrailleuse in the same condition, it was found for the—

Caliber .45, Gatling mitrailleuse No. 150, number of hits, 11.25.

Caliber .45, Gatling mitrailleuse, No. 161, number of hits, 3.72.

The superiority of the revolver cannon is well marked.

Firing with shells against a battalion in column by division at entire distances. (Tests of 25th July, 1873.)

The battalion is represented by 6 targets of 1.80 meters (about 6 feet) height and 35 meters (about 115 feet) width. The distance between is 35 meters (about 115 feet.) The last target 1,795 meters (about 1,963 yards) from the revolver cannon.

Powder-charge, 85 grammes; bursting-charge, 20 grammes; powder of Ripault. The firing is regulated to drop the projectiles between the third and the fourth targets.

Angle of fire, 6° 30′.

Two salvos of 40 shots fired without traversing.

The number per hundred of hits is, for the revolver cannon—

First salvo, 109; the second salvo of 40 shots fired in 30 seconds; second salvo, 245.

For the 1st caliber, Gatling mitrailleuse No. 81: first salvo, 24; second salvo, 48; third salvo, 57.3.

For the .65 caliber Gatling mitrailleuse No. 10: first salvo, 25; second salvo, 35; third salvo, 54; fourth salvo, 18.7.

The Hotchkiss revolving cannon, therefore, produces a much superior effect to that of the mitrailleuse Gatling.

Firing against a steel plate of 10 *millimeters* (*about* 0.3937 *inch*) *thick; distance,* 150 *meters* (*about* 492 *feet*). (*Experiments of July* 25, 1873.)

Three shots.

1. Goes through and explodes in coming out.
2. Goes through and explodes in coming out.
3. The shot, badly directed, hits at left a sheet-iron of 10 millimeters (about 0.3937 inch) thick, supported by a piece of oak of 20 centimeters (about 7.874 inches) square. The projectile exploded in the wood, which was split to the length of about one meter (about (3.28 feet.) The hole measures behind about seven centimeters (about 2.76 inches) of width. The piece of iron detached from the sheet went through the wood and dropped at 4 or 5 meters (about 15 feet) beyond.

SENSIBILITY OF FUSES.

The cannon was pointed seaward and fired.

1. Two shots at an angle of 2′. The shell exploded on touching the water.
2. One shot at + 15′. The shell exploded on touching the water.
3. One shot at 2°. The shell exploded on touching the water.
4. One shot at 3°. The shell exploded on touching the water.
5. One shot at 5°. The shell exploded on touching the water.

TRIAL OF SAFETY OF FUSES (25TH JULY, 1873).

Three shells were suspended by a string, the point downward. When the string was cut the shell with the fuse fell on a sheet-iron plate the height of 3.32 meters (about 11 feet). The fuse did not explode and the mechanism did not move.

TRIAL OF FUSES (EXPERIMENTS 21ST JANUARY, 1874).

All the empty shells penetrated into the earth from 30 to 40 centimeters (about 13 inches) depth. The fuse had exploded in all that were found.

RANGE (EXPERIMENTS OF JANUARY 20, 1874).

Charge of powder, 150 grammes "R. L. G." Some of the projectiles fired at 30° elevation, which were not found, struck the ground at a distance of 5,000 meters (about 5,468 yards).

The projectile fired at 35° elevation had a range exceeding 5,000 meters (exceeding 5,468 yards). Some of the assistants saw it fall, but could not find it because the ground was too rough.

ACCURACY (EXPERIMENTS OF JANUARY, 1874).

Powder-charge, 100 grammes, powder of Ripault; angle of fire, 35°.

Shell.

Mean range, 4,014 meters (about 4,390 yards).
Maximum range, 4,023 meters (about 4,400 yards).
Minimum range, 3,998 meters (about 4,372 yards).
Difference in range, 25 meters (about 27 yards).
Maximum deviation, 64.2 meters (about 70.21 yards).
Minimum deviation, 60.2 meters (about 65.83 yards).
Difference in deviation, 4 meters (about 4.38 yards).

The shells fired hit the ground at over 4,000 meters (about 4,375 yards) distance, within a space of 25 meters (about 27 yards) length and 4 meters (about 4.38 yards) wide.

Solid shot.

Mean range, 4,454 meters (about 4,871 yards).
Maximum range, 4,466 meters (about 4,884 yards).
Minimum range, 4,442 meters (about 4,857 yards).
Difference in range, 24 meters (about 26 yards).
Maximum deviation, 62 meters (about 67.8 yards).
Minimum deviation, 60.6 meters (about 66 yards).
Difference in deviation, 1.4 meters (about 1.5 yards).

The projectiles hit the ground at a distance near 4,500 meters (about 4,921 yards), within a space of 24 meters (about 26 yards) length and 1.4 meters (about 1.5 yards) wide.

Extract from the report upon the Hotchkiss revolving cannon, model of the French marine.—(Experiments of Gavre, February and March, 1877.)

The modifications applied to the cannon-revolver for the service of the marine have had for their principal object the giving to the piece a sufficient lightness and mobility to enable the same man to execute a continuous fire and to rectify the pointing at each shot.

The necessary mobility has been obtained by mounting the piece upon a fork pivoted in a socket, and this is rendered sufficient, because the cannonier who points supports the left shoulder against a trail-piece and holds with the left hand a handle placed under the breech, and, while turning with the right hand the crank, is able at the same time to follow the object with the line of sight.

It is proposed to have some small pieces, which, placed upon different parts of a vessel, shall be able to protect disembarkation from small crafts and torpedo-boats.

To fulfill this object we should have great accuracy up to 2,187 and 2,734 yards, sufficient rapidity of fire, and penetration, at these distances, of plates from .20 inch to .24 inch; also the piercing of sheathing of launches.

PENETRATION OF THE SHELLS.

The shell of 14.85 ounces, of ordinary cast iron, gave dangerous fragments in bursting on its passage through a plate of sheet-steel of .24 inch, with a velocity at impact reduced to 482 feet (corresponding to a distance of 2,187 yards) under an angle of 22°, or with a velocity at impact of 623 feet (corresponding to a distance of 1,640 yards) under an angle of 30°.

It gave more than six dangerous fragments per shot in passing with a velocity at impact of 1,302 feet in normal fire against a steel plate about .6 inch thick. It gave again some dangerous fragments after having traversed 11.8 inches of wood under an angle of 0°, with a velocity of about 722 feet; after having traversed 11.8 inches of wood, under an angle of 30°, with a velocity at impact of 1,302 feet; and after having traversed a wall of 3.9 inches, under an angle of 30°, with a velocity at impact of about 722 feet.

FIRING AT VESSELS IN MOTION.

This firing was easily done by two men, although the gunner was not accustomed to fire upon the sea at a movable target, nor to the sight that was used. This firing showed remarkable accuracy, since fifty good shots were observed out of 108 fires. The balloon which served as a target (31½ inches diameter) was reduced to pieces; and the stem, the upper part of which was attached to the balloon and had 2.36 inches of cross-section, was cut away and riddled with shot; and the remaining stump, of which the lower part was about .45 inch cross-section, bore the trace of many shells, attesting the efficacy of the fire against a target of very small dimensions.

RESISTANCE OF THE CARTRIDGE-CASES EMPLOYED IN FIRING.

It is found that the same case can be used (by re-priming) four or five times.

GENERAL SUMMARY AND CONCLUSIONS.

The Hotchkiss revolving cannon (marine model) fulfils the many conditions for the employment to which it is destined—that is to say, the defense of vessels against small crafts and torpedo-boats.

The commission thought, in addition, that it was fitting to examine if this arm would serve to a good use in the protection of the embarkation of troops.

The extent of its ranges and its longitudinal accuracy are remarkable, and its lateral accuracy is satisfactory.

The results of firing practice aboard ship, executed with shells of 14.85 ounces, showed that the ballistic qualities of the revolving cannon would be utilized in the most difficult conditions of a movable target.

For a distance estimated at the beginning of a volley, and variable, a mean velocity of fire of about one shot in five seconds in regular working and practice is reasonably sufficient to secure the effects of each fire.

The shell of 14.85 ounces, of ordinary cast iron, charged and fitted with a percussion-fuse, normally pierced plates of steel of .24 inch and up to 2,187 yards distance; and under an angle of 30° up to about 1,640 yards. This same shell normally pierced 11.8 inches of oak wood at 547 yards, and 3.9 inches of oak wood under the angle of 30° at the same distance. Its explosion gave, even after the perforation of those obstacles, some dangerous fragments.

The shell of about 1 pound, of the same metal, will have a greater effect, especially at great distances.

Two men are sufficient for serving the cannon.

[Translation.]

Report of the minister of war to the general legislative assembly of Brazil on the Hotchkiss revolving cannon, made at Rio de Janeiro, 1875.

[Extract.]

The artillery committee highly recommend the Hotchkiss revolving cannon, and state that the smallness of its caliber is compensated for by the rapidity of fire, as about 80 rounds per minute can be discharged from it, while one round can only with difficulty be discharged from other systems (Whitworth, Krupp, &c.).

Each shell of the revolving cannon gives 10 to 11 useful fragments; the gun produces, therefore, about 800 fragments per minute. The Whitworth and Krupp guns give only 7 to 9 useful fragments during the same time, having the same range and precision as the revolving cannon.

The maximum range of the gun is 4,500 meters (about 4,921 yards) with French powder, or about 5,000 meters (about 5,468 yards) with our own powder, which at present appears to be of the best quality.

The sample gun purchased by the imperial government, at the request of the artillery committee (though not quite complete, as it was not provided with the shield to protect the gunners against sharpshooters), proved at the experiments on the firing-grounds to be an excellent weapon, as it possesses the following qualities:

Great range.

Perfect accuracy of fire.

Absence of recoil, due to the special brakes.

Quick loading, simple and almost automatic.

Great rapidity of fire.

Metallic cartridge, which can be reloaded on the average 8 times, and allowing the primers to be changed with great facility.

Simple and strong mechanism, composed of only 7 parts, which load, fire, extract, and drop the empty cartridge-shell to the ground.

Complete obturation and forced projectile.

Operation by only four men, who can easily be protected by entrenchment of the gun.

The artillery committee express the opinion that the practical results will perhaps recommend the adoption of this system as the only artillery for our army.

Signed—the secretary of state and minister of war.

Record of firing with caliber 1½-inch Hotchkiss revolving cannon, from September 11, 1876, to February 15, 1877, at Sandy Hook, New York Harbor.

Date.	No. of shot.		Charge.				Projectiles.				Mean observed velocities of the projectiles at 160 feet from the muzzle of the gun, as recorded by Le Boulengé chronograph.	Elevation.	Targets.					Condition of weather.					Remarks.
			Powder.		Cartridge-case.																		
	Preliminary.	Regular firing.	Kind.	Weight.	Length of powder space.	Diameter, exterior.	Kind.	Weight.	Length.	Diameter.			Number of targets.	Distance of first target from gun.	Size.	Distance apart.	Total number of hits.	Thermometer.	Barometer.	Humidity.	Direction of wind.	Strength of wind in miles per hour.	
1876–'77.				Oz.	In.	Inch.		Lb. oz.	In.	In.	Feet.	° ′		Yds.	Feet.	Ft.				Per ct.			
September 11		40	New mortar	4.23	3¼	1.64	Hotchkiss shell.	1 5.5	4.1	1.45													Fired to test working of gun.
September 12		3	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45	1,294												Fired to obtain velocities.
September 12		12	Musket	4.23	3¼	1.64	do	1 5.5	4.1	1.45	1,572												Do.
September 12 and 22		18	Old mortar	4.23	3¼	1.64	do	1 5.5	4.1	1.45	1,458												Do.
September 21	4	72	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45		2 15	4	1,000	11 by 26	125	312	64	30.141	64	L. to R.	8	Target A.
September 22	7	51	do	4.22	3¼	1.64	do	1 5.5	4.1	1.45		5 5	3	2,000	11 by 26	125	56	58	30.204	87	do	21	Target B.
September 22		4	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45			1	200	8 by 13		38						No draught of target made.
September 22		26	do	4.23	3¼	1.64	Hotchkiss canister.	1 9.4	4.56	1.44			1	200	8 by 13		25						Do.
October 3		72	do	4.23	3¼	1.64	Hotchkiss shell.	1 5.5	4.1	1.45													Fired to test working of gun.
November 23	14	101	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45													No draught of target made; 1 miss-fire.
November 24	15		Musket	4.23	3¼	1.64	do	1 5.5	4.1	1.45													Do.
December 2	7	143	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45		1 55	4	1,000	11 by 26	125	1,285	22	29.664	73		22	Target C.
December 2	4	170	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45		4 50	4	2,000	11 by 26	125	963	22	29.664	73		22	Target D; 3 miss-fires.
January 25	13	102	Old mortar	4.23	3¼	1.64	do	1 5.5	4.1	1.45		½	10	200	6 by 52	50	2,140						Target E.
January 25	2	100	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45			2	200	11 by 52	75	1,045						Target F.
February 14		44	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45			2	200	6 by 26	75	309						Target G.
February 15	12	100	do	4.23	3¼	1.64	do	1 5.5	4.1	1.45		2 5	10	1,000	6 by 52	50	1,626						Target H.

NOTE.—November 23, 1876.—Twenty rounds fired in 14½ seconds. Fifty-one rounds fired in 48 seconds. December 2, 1876.—Forty rounds fired in 33 seconds. January 25, 1877.—Ten rounds (averaging) fired in 7½ seconds.

Trials in November and December, 1878, *at ranges of* 100, 200, 300, *and* 440 *yards.*

GENERAL REMARKS.

The trials of the Hotchkiss revolving cannon, made in 1876–'77, demonstrated its merits as an auxiliary arm of our present field systems. As, however, a complete record of its powers and efficiency as a field-gun, especially in its capacity to deliver, at short ranges, a far more deadly and destructive fire than can be attained from any of the present field-artillery projectiles, including canister, had not yet been made by actual practice, it was decided to make experiments and tests to settle the question of its powers in this regard. Accordingly trials were made having this end in view, and the results and conclusions are submitted in this report; also the targets as plotted for the different ranges.

The *fuses* used in these experiments were of the latest model, having two brass wires cast into the lead of the plunger, which, going through slots in the bottom of the case, are held securely in position by the lead safety-plug. The nipple and percussion-cap, at the forward end of the plunger of the old model fuses, have been replaced by a brass box filled with fulminate, the box being formed by turning the edges of a small disk of sheet-metal. The under part of the box is pierced by two vent-holes which come directly over the powder-chamber containing the igniting charge. The open or forward end of the box, filled with its percussion composition, is covered by a disk of tinfoil. The box is secured in its recess at forward end of the plunger by compressing the lead of plunger around it. To prevent premature explosion from handling or in transportation, in case of the loosening and forward movement of the plunger, a small lozenge-shaped piece of thin sheet-brass is secured over the fulminate-box by bending and driving the points at its longer axis into the plunger on either side of the box. A similar piece of brass covers the lower opening of powder-chamber in plunger. With the above exceptions the fuse in its construction and action is the same as the ones described on page 612, Report of the Chief of Ordnance for 1877, and in the report of fuses recently submitted by "The Ordnance Board." (See accompanying Plate XIII.)

Targets.

The targets were made of 1-inch spruce boards, and were three in number for each range. The size, common to all, was 11 by 52 feet, and at each range the three were placed at a distance of 50 feet apart.

Results of firing at Sandy Hook, New York Harbor.

In all these tests at the different ranges the gun was aimed so that the shell would strike about 25 yards in front of target; 4 ounces of new mortar-powder was used as the propelling charge; the shell weighed, loaded, about 1¼ pounds, and the bursting-charge of shell was ⅝ of an ounce of musket-powder.

On the 1st of November 100 rounds were fired at the 200 yard range, with the following results: Hits in first target, 1,444; second, 551; third, 177—total, 2,172. (See target appended, and marked Plate XIV.)

November 15, 100 rounds were fired at both the 300 and 440 yard range. At the 300-yard range the hits were as follows: First target, 697; second, 347; third, 100—total, 1,144. At the 440-yard range there

were, on the first target, 827 hits; on the second, 603; and on the third, 262—making a total of 1,692 hits. (See targets appended, and marked Plates XV and XVI.)

On the 5th of December the final firing was done at the 100-yard range, 100 rounds being fired, with results as follows: Hits on first target, 1,515; second target, 856; third target, 440—total, 2,771. (See target appended, and marked Plate XVII.)

Accuracy and effects.

An examination of the results of firing at Sandy Hook, and accompanying targets, show, at all the ranges fired, accuracy and great destructive effects. The fragments were well distributed, and had great penetrative power, as shown by the number of hits in the third or last target, at each range.

Eighty rounds per minute can be fired from this gun; but, assuming that in deliberate firing sixty rounds are thrown, each shot weighing 1¼ pounds, and bursting on an average into 20 pieces, a continuous and deadly fire of 75 pounds of metal or 1,200 hits per minute is obtained.

CONCLUSIONS.

The results of these trials give full evidences of the efficiency of this arm at the shortest ranges at which it is necessary to use field artillery, and it is the judgment of the Board (with the results of present experiences before it) that the best effects which can be possibly secured from canister or even shrapnel fire will be decidedly more than equaled by the results attainable by the revolving cannon.

The continuousness of the fire attained, also the demoralizing effects likely to arise from the rapidity of the explosions, add decidedly to its advantages over ordinary field and siege pieces (using canister or bullet-shells), in the service of which marked intervals of time in firing necessarily exist.

The previous trials (reported in 1877) demonstrated the efficiency of this arm at the longer ranges of field artillery, and the present ones were only needed to confirm its powers at the shorter ranges usually heretofore provided for by canister fire.

The introduction on trial of this arm therefore, as heretofore recommended, either in separate batteries or as elements of our present field-artillery batteries, it is believed, will prove that greatly increased effectiveness to this arm of the service will ensue, and also probably show that canister fire can be dispensed with materially, if not wholly, as field or siege ammunition.

Record of firing with Hotchkiss revolving cannon, caliber $1\frac{1}{2}$ inches, at Sandy Hook, New York Harbor, from November 1 to December 5, 1878.

No. of rounds fired.	Time.		Powder.			Projectile.			Elevation in degrees.	Bursting charge, musket powder.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
	Month.	Day.	Kind.	Weight.		Kind.	Weight.				
				Lbs.	Oz.		Lbs.	Oz.		Oz.	Fired to strike sand 25 paces in front of first target, so as to burst before reaching same.
32	Nov ..	1	New mortar.	....	4	Hotchkiss	1	4	0	$\frac{5}{8}$	Preliminary shots fired at 200-yard target, getting range.
100	Nov ..	1	.. do	....	4	..do	1	4	0	$\frac{5}{8}$	Fired at three targets in column 50′ apart, 52′ x 11′. First target 200 yards from gun; one shell burst at muzzle. Time of firing 2′ 36″; firing deliberate.
											Total number of hits in three targets, 2,172; pieces through, 1,329; pieces not through, 843.
											Total number of hits in first target, 1,444; pieces through, 919; pieces not through, 525.
											Total number of hits in second target, 551; pieces through, 287; pieces not through, 264.
											Total number of hits in third target, 177; pieces through, 123; pieces not through, 54.
14	Nov ..	15	....do	....	4	..do	1	4	$\frac{1}{4}$	$\frac{5}{8}$	Preliminary shots fired at 300-yard target, getting range.
100	Nov ..	15	... do	....	4	..do	1	4	$\frac{1}{4}$	$\frac{5}{8}$	Fired at 300-yard target. Three miss-fires on first trial, but fired on second trial. Three premature explosions.
											Total number of hits in three targets, 1,144.
											Total number of hits in first target, 697; pieces through 458; pieces not through, 239.
											Total number of hits in second target, 347; pieces through, 249; pieces not through, 98.
											Total number of hits in third target, 100; pieces through, 62; pieces not through, 38.
7	Nov ..	15	....do	....	4	..do	1	4	$\frac{1}{2}$	$\frac{5}{8}$	Preliminary shots fired at 440-yard target, getting range.
100	Nov ..	15	....do	....	4	..do	1	4	$\frac{1}{2}$	$\frac{5}{8}$	Fired at 440-yard target. Five miss-fires on first trial, four of which were fired on second trial; one failed; one fired in its place.
											Total number of hits in three targets 1,692.
											Total number of hits in first target, 827; pieces through, 428; pieces not through, 399.
											Total number of hits in second target, 603; pieces through, 415; pieces not through, 188.
											Total number of hits in third target, 262; pieces through, 138; pieces not through, 124.
9	Dec. .	5	....do	...	4	..do	1	4	$\frac{1}{4}$	$\frac{5}{8}$	Preliminary shots fired at 100-yard target, getting range.
100	Dec...	5	....do	....	4	..do	1	4	$\frac{1}{4}$	$\frac{5}{8}$	Fired at 100-yard target. Five miss-fires on first trial, three of which were fired on second trial, and two failed. Two fired in their place. One shell exploded at muzzle. Three targets in column. First target 100 yards from gun; second, 50 feet in rear of first; third, 50 feet in rear of second.
											Total number of hits in three targets, 2,771; pieces through, 1,756; pieces not through, 1,015.
											Total number of hits in first target, 1,515; pieces through, 900; pieces not through, 615.
											Total number of hits in second target, 856; pieces through, 595; pieces not through, 261.
											Total number of hits in third target, 400; pieces through, 261; pieces not through, 139.

CARRIAGE FOR HOTCHKISS PATENT REVOLVING CANNON

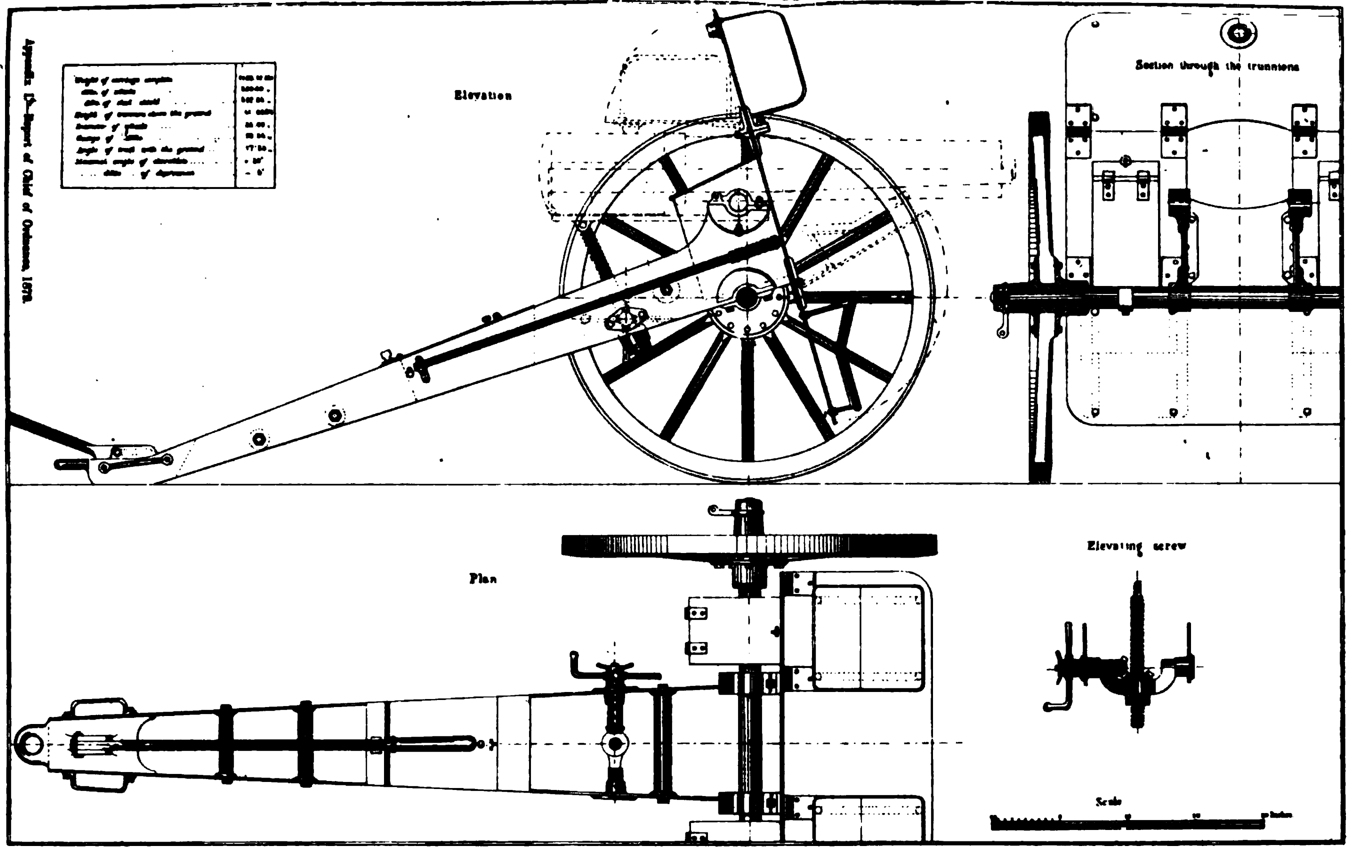
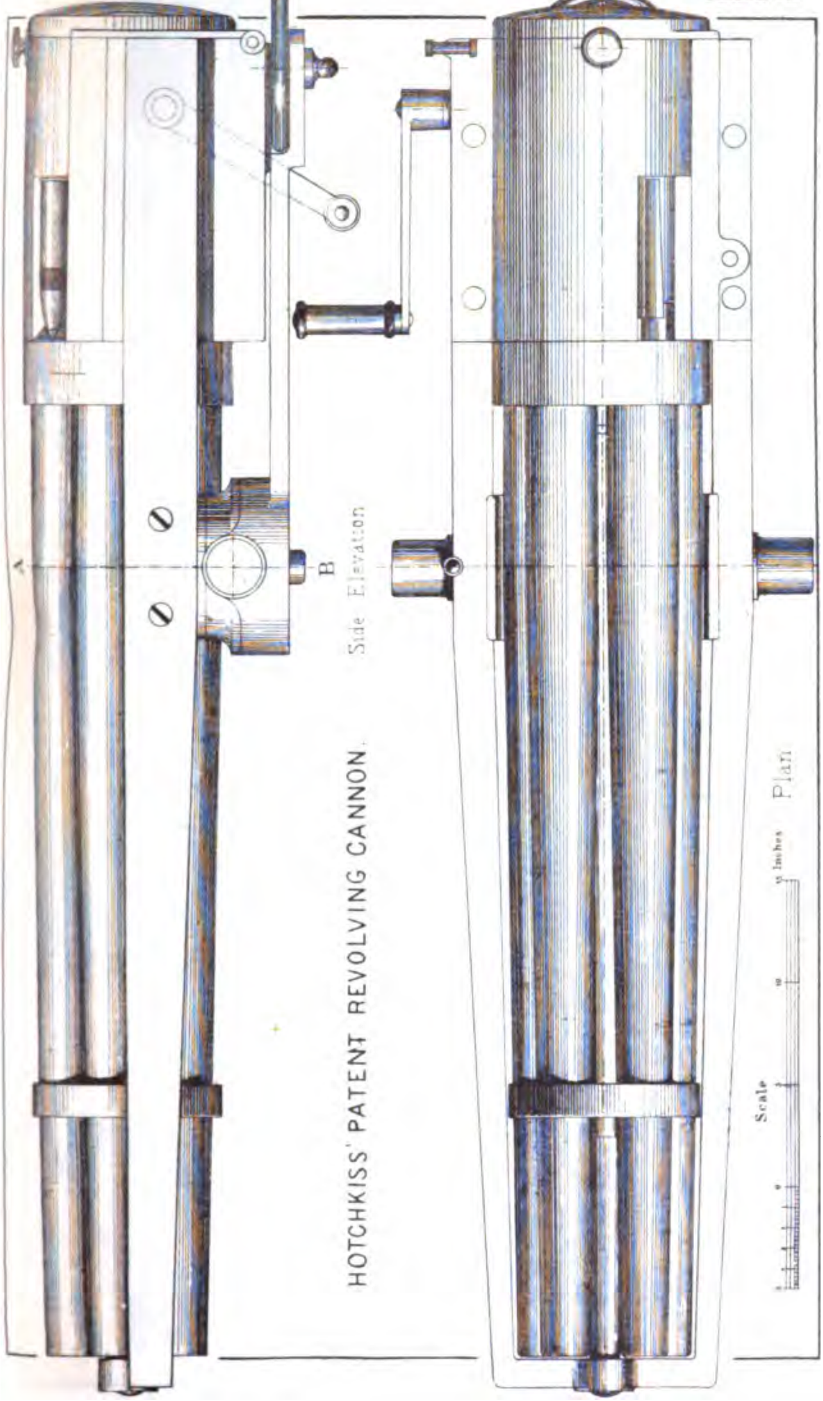
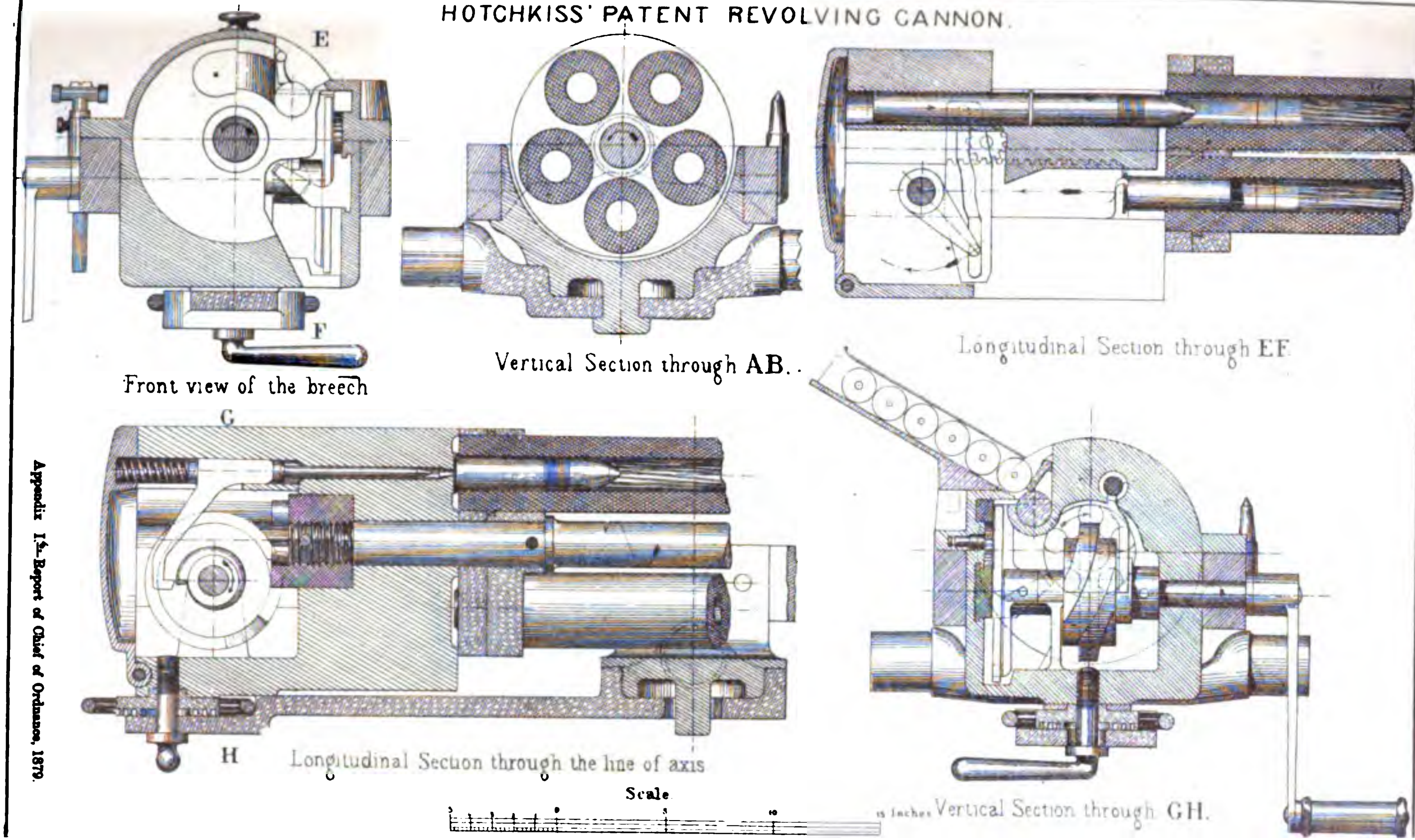


PLATE II.



Appendix I4.—Report of Chief of Ordnance, 1879.

HOTCHKISS' PATENT REVOLVING CANNON.



Front view of the breech

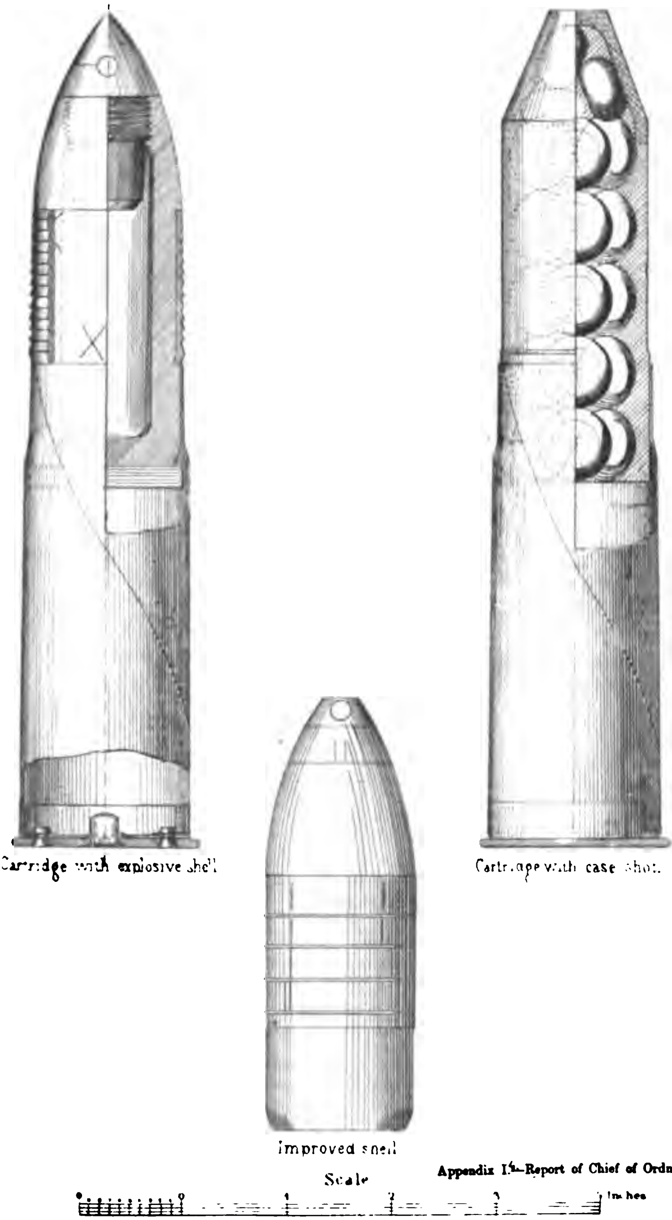
Vertical Section through AB.

Longitudinal Section through EF

Longitudinal Section through the line of axis

Vertical Section through GH.

AMMUNITION FOR THE HOTCHKISS' REVOLVING CANNON.



Cartridge with explosive shell.

Cartridge with case shot.

Improved shell

Scale

Appendix I[1]—Report of Chief of Ordnance, 1879.

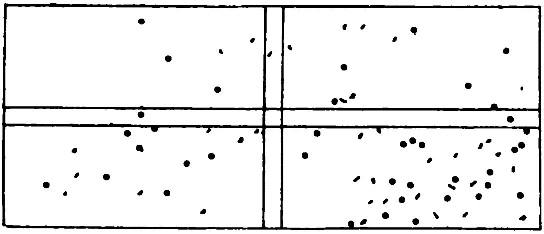
A

Sept. 21st 1876

Hotchkiss Revolving Cannon

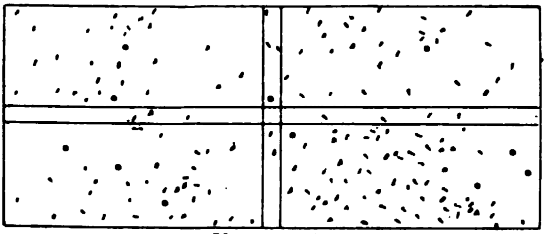
Target Record 1000 Yards.

No. 1.



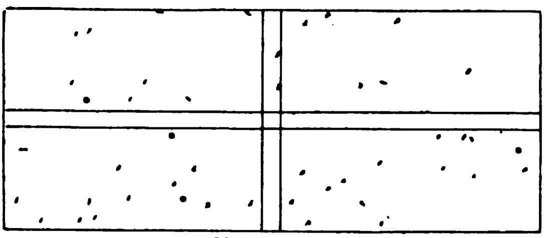
Number of Hits 77.

No. 2.



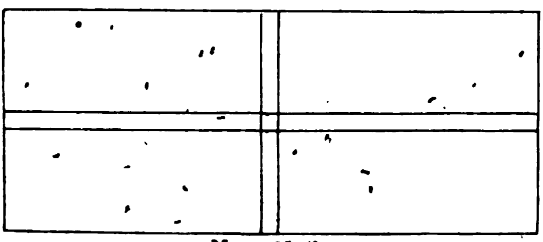
Number of Hits 171.

No. 3.



Number of Hits 45.

No. 4.



Number of Hits 19

Legend:
- Targets [illegible] feet by [illegible] feet;
- Distance between targets [illegible] feet.
- Total Number of Hits 312
- Number of [illegible] 72.

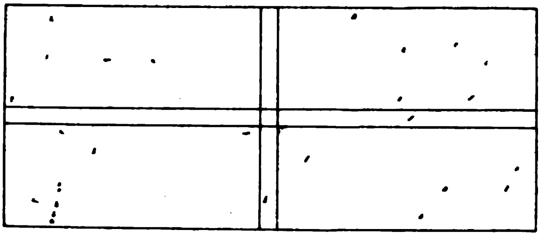
B.

Sept. 22nd 1876.

Hotchkiss Revolving Cannon

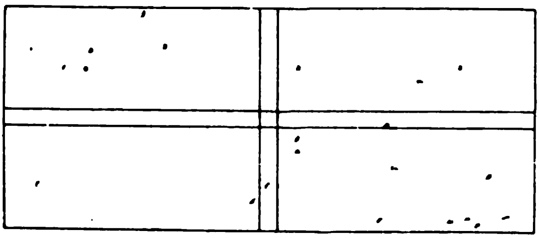
Target Record 2000 Yards

No. 1.



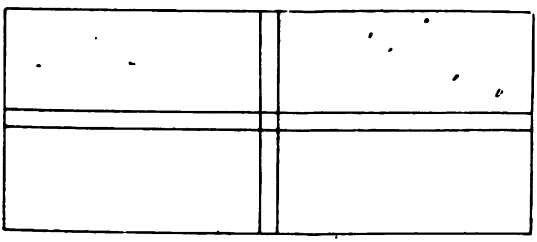
Number of Hits 28.

No. 2.



Number of Hits 21.

No. 3.



Number of Hits 7.

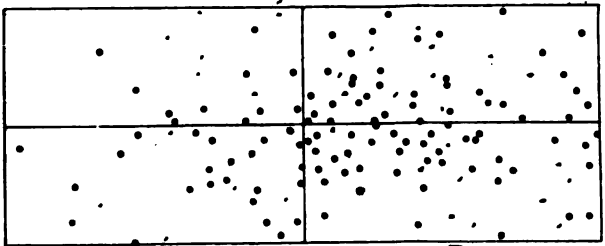
Legend: Target 11 feet by 28 feet.
Distance between targets 125 feet.
Total Number of hits 56.
Number of shell fired 81

C.

Hotchkiss Revolving Cannon Dec. 2nd 1878.

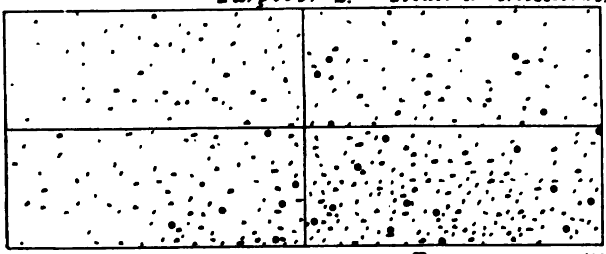
No of Rounds fired 148 1½" Cal. 1000 Yards.

Target No 1. Total Numb. of Hits 145.



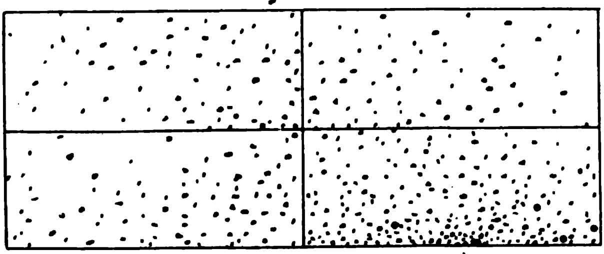
• Direct Hits 112. ▴ Pieces through 24. ▴ Pieces not through 9.

Target No 2. Total Numb. of Hits 401.



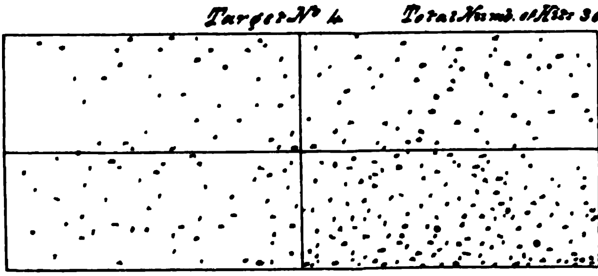
• Direct Hits ' Pieces through 276. ▴ Pieces not through 112.

Target No 3. Total Numb. of Hits 434.



• Direct Hits 5. ' Pieces through 284. ° Pieces not through 145.

Target No 4. Total Numb. of Hits 305.



• Direct Hits 2. ' Pieces through 194. ▴ Pieces not through 108.

Target 20 feet x 11 feet. 125 feet apart.

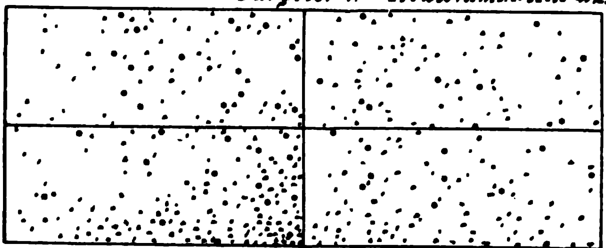
D.

PLATE VIII.

Hotchkiss Revolving Cannon Dec. 2nd 1876

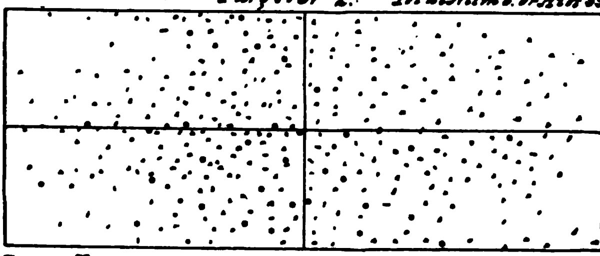
N° of Rounds fired 170. 1½" Cal. 2000 Yards.

Target N° 1. Total Numb. of Hits 402.



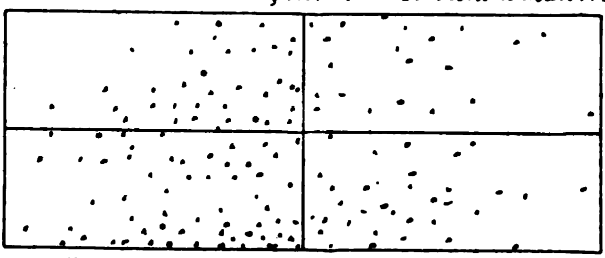
Direct Hits 50. Pieces through 182 Pieces not through 170.

Target N° 2. Total Numb. of Hits 333.



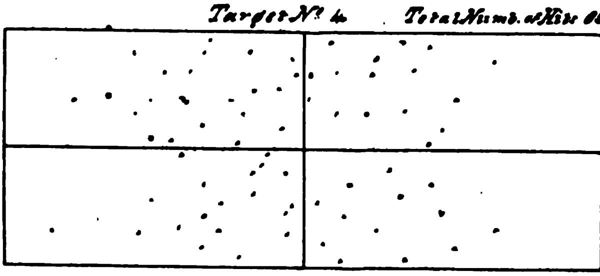
Direct Hits 31. Pieces through 120. Pieces not through 176.

Target N° 3. Total Numb. of Hits. 149.



Direct Hits 4. Pieces through 64 Pieces not through 81.

Target N° 4. Total Numb. of Hits 60.



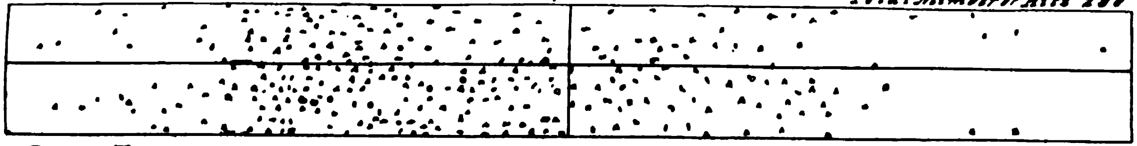
Direct Hits 2. Pieces through 26 Pieces not through 42.

Appendix I.h—Report of Chief of Ordnance, 1879.

Target 26 feet x 11 feet 125 feet apart.

Target No. 8.

Total Number of Hits 280



• Direct Hits 5 ◖ Pieces through 248 ◗ Pieces not through 27.

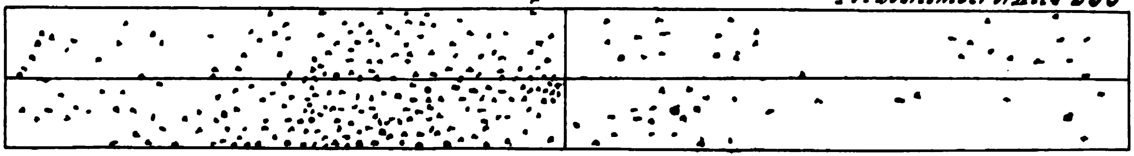
Target No. 9

Total Number of Hits 243

• Direct Hits 5 ◖ Pieces through 201. — Pieces not through 37.

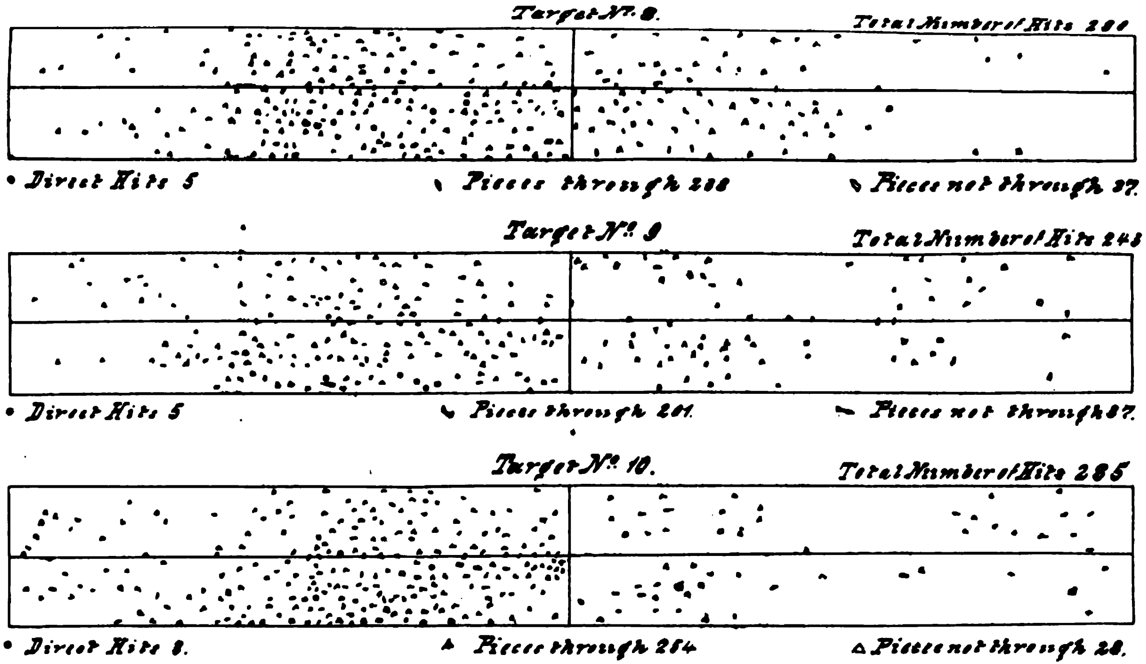
Target No. 10.

Total Number of Hits 285



• Direct Hits 8. ▲ Pieces through 254 △ Pieces not through 23.

Target 52 feet × 6 feet 50 feet apart.



Target 52 ft. × 6 ft. 50 feet apart.

PLATE X.

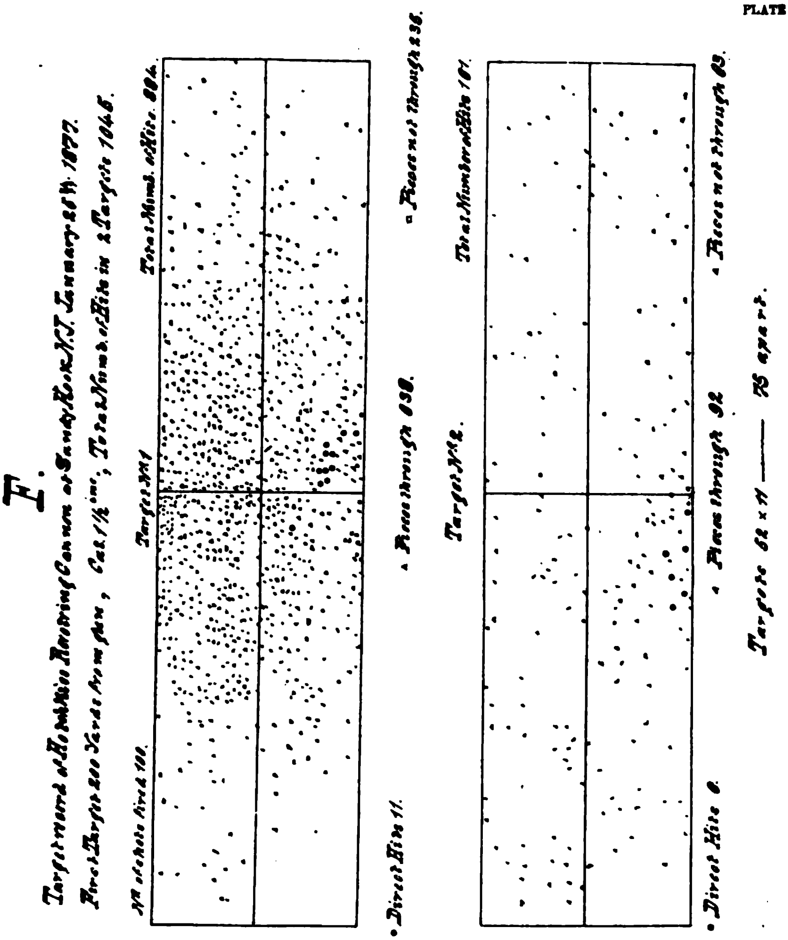


PLATE XI.

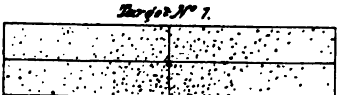
G.

Hotchkiss Revolving Cannon Cal. 1½ in Feb. 2nd 1877 at Sandy Hook N.J.

First Target 200 Yards from Gun. Number of Shots Fired 44.

Total Number of Hits in 2 Targets 307.

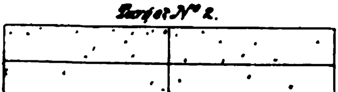
Target No. 1.



Direct Hits 0 · through 128 · not through 153

Total Numb. of Hits in 1st Target 287.

Target No. 2.



Direct Hits 0 · through 11 · not through 9.

Total Numb. of Hits in 2nd Target 20.

Target 26 ft. × 6 ft. 75 ft. apart.

H.

Hotchkiss Rev. Cannon Cal. 1.5 ins Feb. 16th 1877 at Sandy Hook N. J.

First Target 1000 Yards from Gun   Number of Shots fired 700

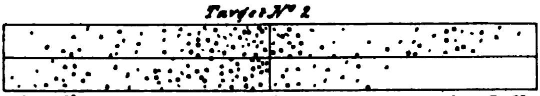
Total Number of Hits in 10 Targets 1628.

Target No 1.

• Direct Hits 33   • through 67   • not through 29.

Total Numb. of Hits in 1st Target 129.

Target No 2



• Direct Hits 58   • through 68   • not through 60

Total Numb. of Hits in 2nd Target 186

Target No 3.

• Direct Hits 39   through 132   • not through 160

Total Numb. of Hits in 3rd Target 331

Target No 4

• Direct Hits 24   • through 98   • not through 200

Total Numb. of Hits in 4th Target 322

Target No 5

• Direct Hits 9   • through 52   • not through 191.

Total Numb. of Hits in 5th Target 252

Target No 6.

Direct Hits 3   • through 63   • not through 126

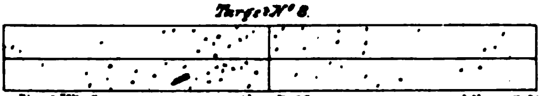
Total Numb. of Hits in 6th Target 191

Target No 7.

• Direct Hits 4   • through 44   • not through 92

Total Numb. of Hits in 7th Target 140

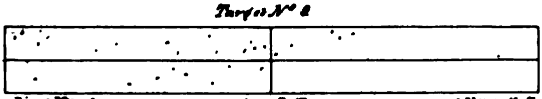
Target No 8.



• Direct Hits 7   • through 36.   • not through 24

Total Numb. of Hits in 8th Target 67

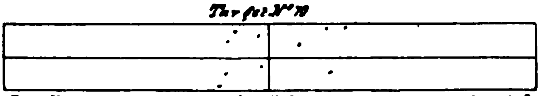
Target No 9



• Direct Hits 0   • through 17   • not through 7.

Total Numb. of Hits in 9th Target 24

Target No 10



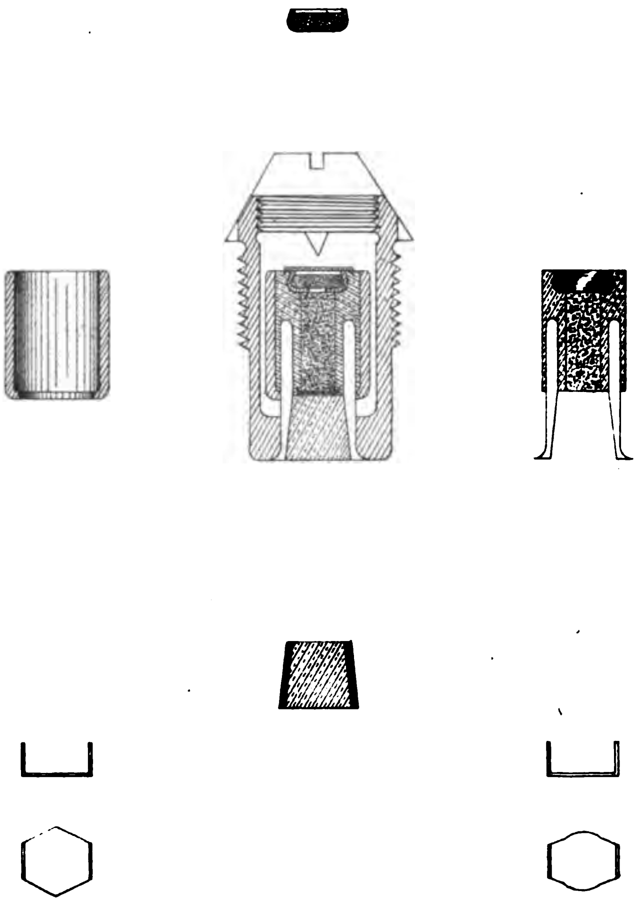
• Direct Hits 0   • through 8   • not through 2

Total Numb. of Hits in 10th Target 10

Appendix I 2. Report of Chief of Ordnance 1879

Target 62 feet × 6 feet ..... 60 feet apart.

HOTCHKISS PERCUSSION FUSE.



Scale.

10 9 8 7 6 5 4 3 2 1 0 1 Inch

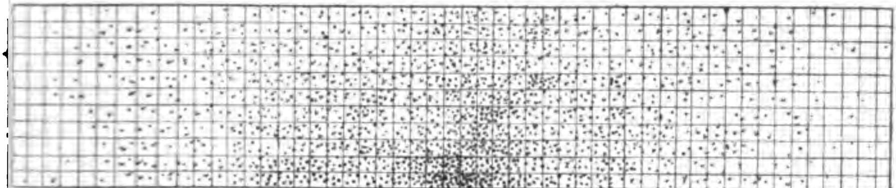
Target Record Hotchkiss Revolving Cannon Cal. 1.5 inch at Sandy Hook N.J. Nov. 1st 1878

First target 200 yards from gun second target 50 feet in rear of first third target 50 feet in rear of second

Number of shots fired 100

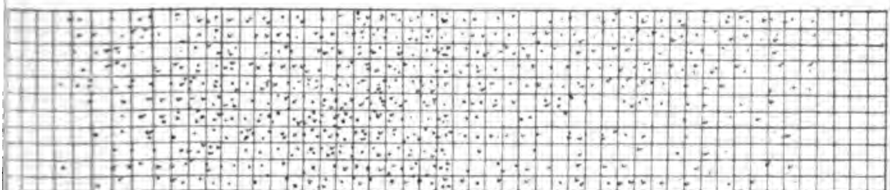
Total number of hits in the three targets 2172 pierced through 1329 - pierced not through 843

Target No. 1.



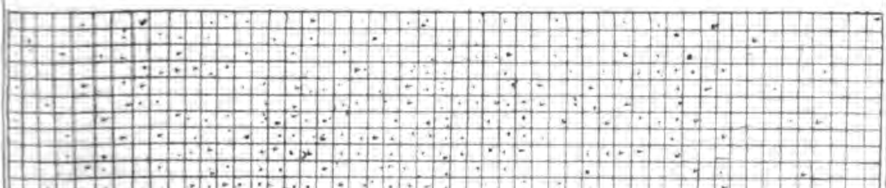
Number of hits in first target 1444 (pierced through 919 pierced not through 525) Target 52 x 11 made of 1in spruce

Target No. 2.



Number of hits in second target 551 - (pierced through 287 pierced not through 264.) Target 52 x 11 - made of 1in spruce

Target No. 3.



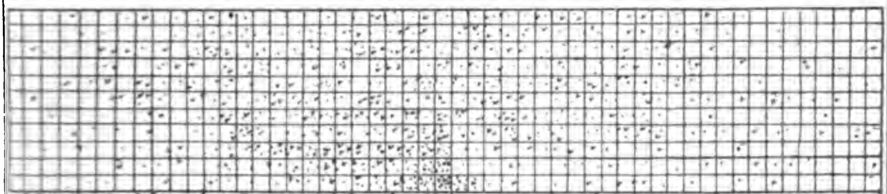
Number of hits in third target 177 (pierced through 123 pierced not through 54) Target 52 x 11 made of 1in spruce

Target Record – Hotchkiss Revolving Cannon. Cal 1½ in. at Sandy Hook N.J. Nov 15th 1878

Three targets in column. First target 300 Yards from gun. Second target 50 feet in rear of first. Third target 50 feet in rear of second.

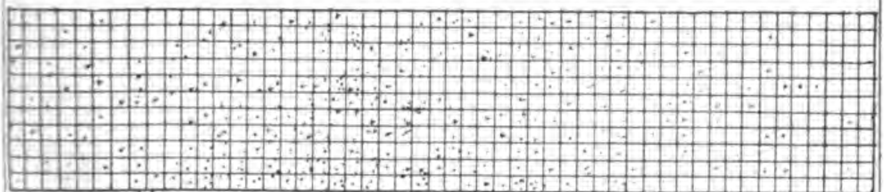
Number of shots fired 100. Total number of hits 1144

Target No. 1.



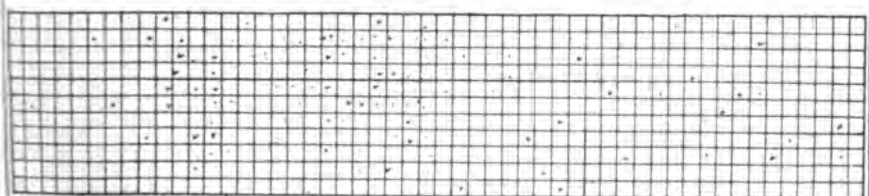
Total number of hits in first target 697. (Pieces through 448 – Pieces not through 249)

Target No. 2.



Total number of hits in second target 347 – (Pieces through 249 Pieces not through 98)

Target No. 3.



Total number of hits in third target 100 – (Pieces through 62 not through 38)

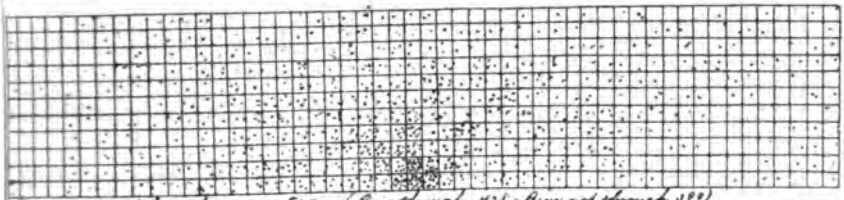
Targets 11' × 52' Made of 1 inch Spruce boards. Pieces through marked • Not through •

Target Record of Hotchkiss Revolving Cannon Cal. 1½ in at Sandy Hook N.J. Nov 15th 1878

Three targets in column. First target 100 yards from gun. Second target 50 feet in rear of first. Third target 50 feet in rear of second.

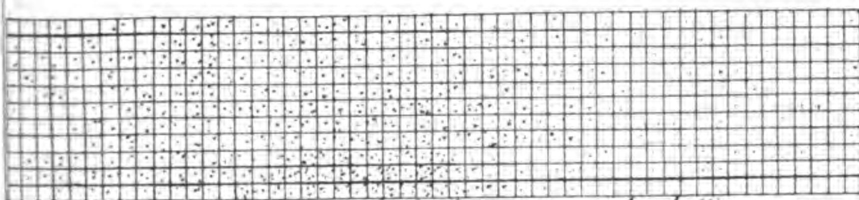
Number of shots fired 100   Total number of hits 1692

Target No. 1.



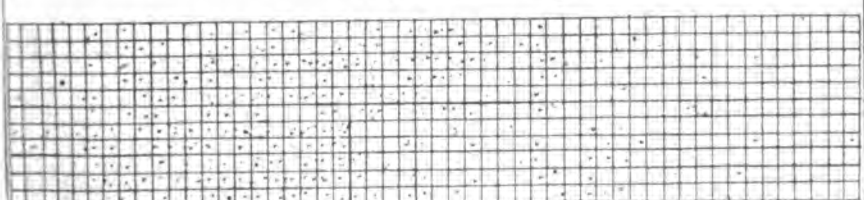
Total number of hits in first target 827 (Pierced through 428 - Pierce not through 399)

Target No. 2.



Total number of hits in second target 603 (Pierce through 415 Pierce not through 188)

Target No. 3.



Total number of hits in third target 262. (Pierce through 138 – Pierce not through 124)

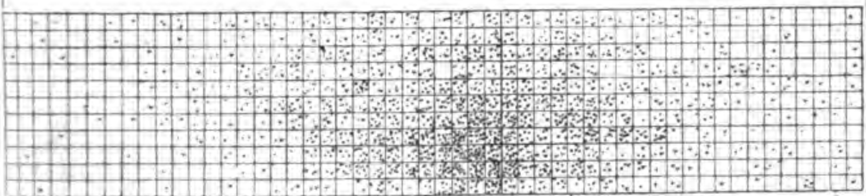
Targets 11' X 52' Made of 1 in Spruce boards   Pierce through marked · Pierce not through ·

Target Record of Hotchkiss Revolving Cannon Cal 1½ inch at Sandy Hook N.J. Dec 5th 1878

Three targets in column First target 100 yards from gun, Second target 50 feet in rear of first Third target 50 feet in rear of second

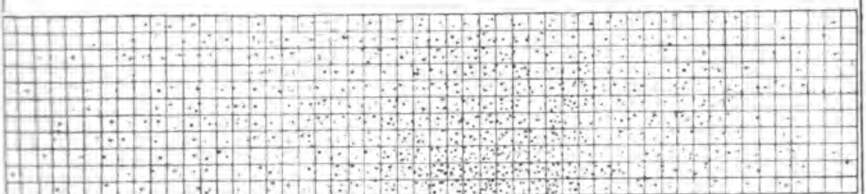
Number of shots fired 100 Total number of hits in three targets 2771

Target No. 1.



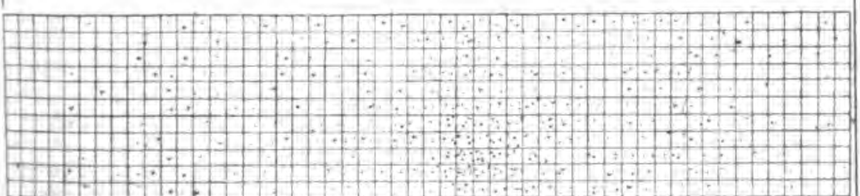
Total number of hits in first target 1515 (Pieces through 900 Not through 615)

Target No. 2.



Total number of hits in second target 856 (Pieces through 595 Not through 261)

Target No. 3.



Total number of hits in third target 400 (Pieces through 261 Not through 139)

Targets 11' x 52' Made of 1 inch Spruce boards Pieces through marked · Pieces not through -

APPENDIX I[5].

FLANK-DEFENSE CARRIAGE FOR HOTCHKISS REVOLVING CANNON, CALIBER 1.5 INCH.

(Seven plates.)

DESCRIPTION OF CARRIAGE.

(Plates I, II, and III.)

(Furnished by the Constructor of Ordnance.)

In order to fit the Hotchkiss revolving cannon for introduction in our sea-coast forts as a flank-defense gun, as contemplated by the department, it became necessary to devise a carriage properly dimensioned for our casemates, of the required strength, and having the maneuvering appointments to meet the requirements of this special service. A wrought-iron carriage attached to and working on a wrought-iron chassis or platform constitutes the general features of the system.

The use of plain frames for the carriage and chassis, covered by thin plates riveted to the frames, was deemed the best for strength, lightness, and economy; the different parts being assembled by ordinary transoms, sufficient in number and so located in the system as to secure the necessary stiffness and solidity. Accordingly, the carriage and its platform have been constructed as follows:

The carriage is composed of two cheeks, each constructed by riveting two plates $\frac{1}{4}$ inch thick to a skeleton frame 1 by $1\frac{3}{4}$ inch thick, and the cheeks in turn are assembled by two transoms, one located at the front, and the other at the rear, and the latter so constructed as to afford an oscillating bed for the reception of the elevating screw and its beveled gear. (See Plate II.)

The chassis consists of two rails constructed on the same general principles as the carriage-cheeks, the frame being bar-iron 1 by $1\frac{3}{4}$ inches thick, and the side plates having a thickness of $\frac{1}{4}$ inch; three transoms of $\frac{1}{2}$ and $\frac{3}{4}$ inch iron (located as shown in Plate III) assemble the parts.

The forks, wheels, &c., and system of training, and the details of chassis proper, are shown in Plate III, and the gun-carriage and chassis (with its tongue connected with pintle) are shown in position in our present flank-defense casemates, in Plate I.

The bottom or lower barrel being the one destined to deliver the fire in this system when in action, the dimensions of the carriage and platform have been so determined as to place the axis of this barrel (when horizontal) in the center of the throat of the embrasure, this being the proper initial point for elevation and depression and service.

The carriage is firmly secured (when in battery and ready for service) to its chassis by means of a screw, *a* (see Plate I), operated by a lever, *b*, clamping a square plate, P, to a slotted plate, *c c c*, placed underneath and extending the entire length of the chassis, and secured to the latter by its front and rear transoms, *t* and *t′*, respectively. To give the play necessary to avoid rigidity and the consequent effects of shocks in firing, a rubber spring, *r r*, is located at the front of the chassis, and secured as shown in Plate I. The ordinary pintle-tongue, *p*, connects the system with the pintle located in the front wall of the casemate.

Elevating and depressing are accomplished by means of an elevating screw, *s*, working in a screw-nut, *u*, having a bevel-gear on its exterior which is turned by a miter-wheel on the end of a shaft, *x x*, which passes through the left cheek of the carriage and is revolved by the hand-wheel,

w w. The elevating-screw is permanently attached to the gun by the lug *g* and pin; the transom, having an oscillating motion to accommodate the screw, being pivoted to the two cheeks of the carriage. (See drawing.)

When it is necessary to withdraw the gun from its embrasure (shown in section in plate I), the plate P is relieved by operating the screw *a*, and the carriage, free to slide on its chassis, is drawn back by an ordinary windlass in connection with a rope and crank.

The chassis is especially designed in length with a view to meet this operation which may result from temporary disablements in action or which may be necessary for the purposes of cleaning and immediate repairs. When so drawn back, and sufficiently far to clear the walls of the embrasure, the carriage with its gun can be swung at right angles to the chassis and the gun thus placed in position for any desired examination, cleaning, or relief from impediments or disabilities.

The *ammunition* used in all the tests was that described in the Report of the Chief of Ordnance for 1877, page 612; the shell being fitted with the Hotchkiss percussion-fuse described in report of the Board of December 17, 1878 (Ordnance Notes, No. 94).

RESULTS OF FIRING AT SANDY HOOK.

The object of the firing was to test the stability and general workings of the carriage and the accuracy of fire from it. To make the trials more complete, targets were made with the revolving cannon, cal. 1''.5, mounted, one on this carriage and one on the Hotchkiss field-carriage.

On the 9th of April, after 3 sighting shots to get the proper elevation, 20 rounds were fired from each gun at a target 11 by 52 feet, made of 1-inch spruce boards, and at a distance of 500 yards. The number of hits in both cases was 20, and all direct. The mean deviation from the center of impact was, for the flank-defense carriage, 2'.139; for the field-carriage, 1'.734. (See record appended and Plates IV and V.)

On the 16th of same month firings, under similar conditions to those of the 9th, were made at 1,000 yards, 20 rounds in each case fired; with the flank-defense carriage there were two failures to hit target, the mean deviation from center of impact of the 18 hits being 3'.1194; with the field-carriage all of the shots hit, the mean deviation being 3'.70416. (See Plates VI and VII.)

In order to test the workings of the carriage for flank-defense purposes, a wooden casemate was constructed, all of the dimensions of which, as to height and width of embrasure, &c., were obtained from the drawings furnished by the Engineer Department. In all the firings under the different angles, both of elevation and depression, and also in its traverse, the carriage worked very satisfactorily.

CONCLUSIONS.

All of the different functions required to be performed by the carriage were satisfactorily shown in the tests, and the system proved itself easy of traverse, elevation, and depression for the different circumstances of fire for flank-defense service. Also the feature securing a withdrawal of the gun from the embrasure—a necessity which it is apparent will arise under the varying circumstances of service—has shown in the experiments to serve its purpose with promptness and efficiency.

The carriage is strong in all its parts; well adapted as a system, both in construction and essential features, for all the contingencies required of it in service, sightly in its lines, and is recommended as a standard to be followed in the manufacture of flank-defense carriages for the Hotchkiss revolving cannon, heretofore tested and approved by the Board.

Target record of firing with 1½″ Hotchkiss revolving cannon, No. 255, at Sandy Hook, New York Harbor, from April 9 to April 16, 1879.

Number of rounds.	Time.	Powder. Kind.	Powder. Weight. Lbs.	Powder. Weight. Oz.	Projectile. Kind.	Projectile. Weight. Lbs.	Projectile. Weight. Oz.	Elevation in degrees.	Distance from center of target, in feet. Vertical. Above.	Vertical. Below.	Horizontal. Right.	Horizontal. Left.	Distance from center of impact, in feet. Vertical. Above.	Vertical. Below.	Horizontal. Right.	Horizontal. Left.	Remarks.
1	1879. April 9	New mortar		4	Hotchkiss	1	4	[illegible]									Fired at 500-yard target, sighting shots.
1	...do	...do		4	...do	1	4	[illegible]									
1	...do	...do		4	...do	1	4	[illegible]									
1	...do	...do		4	...do	1	4	[illegible]	2.67		0.83		3.87			5.32	Gun mounted on flank-defense carriage. Fired at 500-yard target. Target 11′ × 52′. made of one-inch spruce boards. Number of shots fired, 20. Number of hits (direct) in target, 20. One cartridge missed fire on first trial; fired on second trial. Firing during 20 rounds continuous. Mean vertical deviation from center of impact, 1.408. Mean horizontal deviation from center of impact, 1.611. Mean deviation from center of impact, 2.139.
1	...do	...do		4	...do	1	4	[illegible]	3.14		2.83		3.84			3.32	
1	...do	...do		4	...do	1	4	[illegible]	1.42		9.17		2.12		3.02		
1	...do	...do		4	...do	1	4	[illegible]	1.41		9.33		2.11		3.18		
1	...do	...do		4	...do	1	4	[illegible]	.17		4.17		.87			1.98	
1	...do	...do		4	...do	1	4	[illegible]	.00		6.42		.70		.27		
1	...do	...do		4	...do	1	4	[illegible]	.25		6.58		.95		.43		
1	...do	...do		4	...do	1	4	[illegible]		0.58	8.25		.12		2.10		
1	...do	...do		4	...do	1	4	[illegible]		1.42	8.00			0.72	1.85		
1	...do	...do		4	...do	1	4	[illegible]		1.67	9.33			.97	3.18		
1	...do	...do		4	...do	1	4	[illegible]		1.00	6.08			.30		.07	
1	...do	...do		4	...do	1	4	[illegible]		1.33	5.67			.63		.48	
1	...do	...do		4	...do	1	4	[illegible]		1.42	5.92			.72		.23	
1	...do	...do		4	...da	1	4	[illegible]		1.50	6.50			.80	.35		
1	...do	...do		4	...do	1	4	[illegible]		1.67	5.28			.97		.87	
1	...do	...do		4	...do	1	4	[illegible]		2.25	6.00			1.55		.15	
1	...do	...do		4	...do	1	4	[illegible]		2.03	6.75			1.33	.60		
1	...do	...do		4	...do	1	4	[illegible]		2.43	7.28			1.73	1.13		
1	...do	...do		4	...do	1	4	[illegible]		2.26	4.53			1.56		1.62	
1	...do	...do		4	...do	1	4	[illegible]		3.50	4.08			2.80		2.07	
23	Total								9.06	23.06	123.00		14.08	14.08	16.11	16.11	
									14.00÷20=.70		123.00÷20=6.15		28.16÷20=1.408		32.22÷20=1.611		

Target record of firing with 1¼" Hotchkiss revolving cannon, No. 255, at Sandy Hook, New York Harbor, from April 9 to April 16, 1879—Continued.

Number of rounds.	Time.	Powder.			Projectile.				Elevation in degrees.	Distance from center of target, in feet.				Distance from center of impact, in feet.				Remarks.
		Kind.	Weight.		Kind.	Weight.			Vertical.		Horizontal.		Vertical.		Horizontal.			
			Lbs.	*Oz.*		*Lbs.*	*Oz.*		Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
	1879.																
1	April 16	New mortar	.....	4	Hotchkiss	1	4	2⅛	5.00	....	0.25	....	3.245	....	....	0.73	Gun mounted on flank-defense carriage. Firing continuous. Fired at 1,000-yard target. Target 11' x 52', made of one-inch pine boards. Number of shots fired, 20. Number of hits (direct), 18. Number of misses, 2. One cartridge missed fire; one fired in its place. Mean vertical deviation from center of impact, 1.6694. Mean horizontal deviation from center of impact, 2.63554. Mean deviation from center of impact, 3.11974.
1	...do	...do	.....	4	...do	1	4	2⅛	2.50	....	.33	....	.745	....	....	.65	
1	...do	...do	.....	4	...do	1	4	2⅛	2.83	....	....	0.25	1.075	....	....	1.23	
1	...do	...do	.....	4	...do	1	4	2⅛	2.17	....	1.08	....	.415	....	0.10	....	
1	...do	...do	.....	4	...do	1	4	2⅛	3.75	....	-1.83	....	1.995	....	.85	....	
1	...do	...do	.....	4	...do	1	4	2⅛	4.25	....	2.08	....	2.495	....	1.10	....	
1	...do	...do	.....	4	...do	1	4	2⅛	2.00	....	3.50	....	.245	....	2.52	....	
1	...do	...do	.....	4	...do	1	4	2⅛	.67	....	....	.17	....	1.085	....	1.15	
1	...do	...do	.....	4	...do	1	4	2⅛	.83	....	....	.67	....	.925	....	1.65	
1	...do	...do	.....	4	...do	1	4	2⅛	.92	....	....	1.42	....	.835	....	2.40	
1	...do	...do	.....	4	...do	1	4	2⅛	....	0.33	....	3.58	....	2.085	....	4.56	
1	...do	...do	.....	4	...do	1	4	2⅛	2.00	....	....	1.42	.245	....	....	2.40	
1	...do	...do	.....	4	...do	1	4	2⅛	Miss	....	....	....	....	....	....	....	
1	...do	...do	.....	4	...do	1	4	2⅛	Miss	....	....	....	....	....	....	....	
1	...do	...do	.....	4	...do	1	4	2⅛	1.83	....	....	3.83	.075	....	....	4.81	
1	...do	...do	.....	4	...do	1	4	2⅛	5.00	....	....	2.92	3.245	....	....	3.90	
1	...do	...do	.....	4	...do	1	4	2⅛	....	1.58	.83	....	....	3.335	....	.15	
1	...do	...do	.....	4	...do	1	4	2⅛	....	3.00	3.33	....	....	4.755	2.35	....	
1	...do	...do	.....	4	...do	1	4	2⅛	....	.25	6.50	....	....	2.005	5.52	....	
1	...do	...do	.....	4	...do	1	4	2⅛	3.00	....	12.17	....	1.245	....	11.19	....	
20	Total								36.75	5.16	31.90	14.26	15.025	15.025	23.63	23.63	
									31.59÷18=1.755		17.64÷18=.98		30.050÷18=1.66944		47.26÷18=2.63554		

Target record of firing with $1\frac{1}{2}''$ Hotchkiss revolving cannon, No. 13, at Sandy Hook, New York Harbor, from April 9 to April 10, 1879.

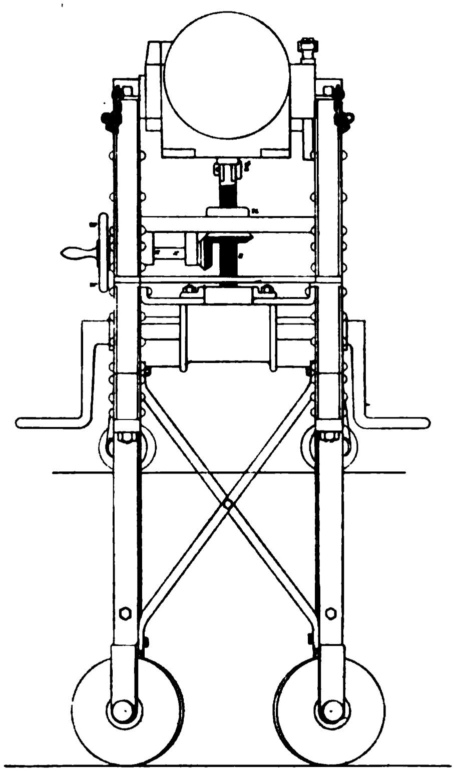
Number of rounds.	Time.	Powder. Kind.	Powder. Weight. Lbs.	Powder. Weight. Oz.	Projectile. Kind.	Projectile. Weight. Lbs.	Projectile. Weight. Oz.	Elevation in degrees.	Distance from center of target, in feet. Vertical. Above.	Vertical. Below.	Horizontal. Right.	Horizontal. Left.	Distance from center of impact, in feet. Vertical. Above.	Vertical. Below.	Horizontal. Right.	Horizontal. Left.
	1879.															
1	April 9	New mortar	......	4	Hotchkiss.	1	4	1	....	1.67	....	6.00	....	1.62	5.13	....
1	...do ...	....do	......	4	....do	1	4	1	....	.83	....	8.50	....	.78	2.63	....
1	...do ...	....do	......	4	....do	1	4	1	....	.25	....	9.75	....	.20	1.38	....
1	...do ...	....do	......	4	....do	1	4	1	....	.50	....	10.25	....	.45	.88	....
1	...do ...	....do	......	4	....do	1	4	1	....	.00	....	10.75	0.05	....	.38	....
1	...do ...	....do	......	4	....do	1	4	1	....	.23	....	11.00	....	.18	.13	....
1	...do ...	....do	......	4	....do	1	4	1	....	1.33	....	11.00	....	1.28	.13	....
1	...do ...	....do	......	4	....do	1	4	1	....	.83	....	10.92	....	.78	.21	....
1	...do ...	....do	......	4	....do	1	4	1	....	2.73	....	10.08	....	2.68	1.05	....
1	...do ...	....do	......	4	....do	1	4	1	....	.82	....	12.00	....	.77	....	0.87
1	...do ...	....do	......	4	....do	1	4	1	....	.42	....	12.06	....	.37	....	.93
1	...do ...	....do	......	4	....do	1	4	1	....	.42	....	12.25	....	.37	....	1.12
1	...do ...	....do	......	4	....do	1	4	1	....	.42	....	13.50	....	.37	....	2.57
1	...do ...	....do	......	4	....do	1	4	1	.50	....	....	12.92	.55	....	....	1.79
1	...do ...	....do	......	4	....do	1	4	1	1.19	....	....	12.33	1.24	....	....	1.20
1	...do ...	....do	......	4	....do	1	4	1	1.33	....	....	8.90	1.38	....	2.23	....
1	...do ...	....do	......	4	....do	1	4	1	1.33	....	....	11.22	1.38	....	....	.09
1	...do ...	....do	......	4	....do	1	4	1	1.44	....	....	11.00	1.49	....	.13	....
1	...do ...	....do	......	4	....do	1	4	1	2.33	....	....	13.25	2.38	....	....	2.12
1	...do ...	....do	......	4	....do	1	4	1	1.33	....	....	14.92	1.38	....	....	3.79
20	Total								9.45	10.45	....	222.60	9.85	9.85	14.28	14.28
									1.00 + 20 = .05		222.60 + 20 = 11.13		19.70 + 20 = .985		28.56 + 20 = 1.428	

Remarks:

Gun mounted on field-carriage.
Fired at 500-yard target.
Target 11′ x 52′; made of 1″ spruce boards.
Number of rounds fired, 20.
Number of hits (direct) in target, 20.
Firing during 20 rounds was continuous.
Mean vertical deviation from center of impact, .985.
Mean horizontal deviation from center of impact, 1.428.
Mean deviation from center of impact, 1.734.

Target record of firing with 1¼" Hotchkiss revolving cannon, No. 13, at Sandy Hook, New York Harbor, from April 9 to April 16, 1879—Continued.

Number of rounds.	Time.	Powder.			Projectile.			Elevation in degrees.	Distance from center of target, in feet.				Distance from center of impact, in feet.				Remarks.
		Kind.	Weight.		Kind.	Weight.			Vertical.		Horizontal.		Vertical.		Horizontal.		
									Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
	1879.		*Lbs.*	*Oz.*		*Lbs.*	*Oz.*										
1	April 16	New mortar	.....	4	Hotchkiss	1	4	2⅛	....	....	....	....	....	....	....	....	Fired at 1,000-yard target; sighting shots.
1	...do	...do	.....	4	...do	1	4	2⅛	....	....	....	....	....	....	....	....	
1	...do	...do	.....	4	...do	1	4	2⅛	....	3.50	1.17	....	....	3.875	6.5365	....	Firing continuous. Fired at 1,000-yard target. Target, 11' x 52'; made of 1" spruce boards. Number of shots fired, 20. Number of hits (direct), 20. Gun mounted on field-carriage. Mean vertical deviation from center of impact, 2.058. Mean horizontal deviation from center of impact, 3.02985. Mean deviation from center of impact, 3.70416.
1	...do	...do	.....	4	...do	1	4	2⅛	....	1.50	....	2.00	....	1.875	3.3665	....	
1	...do	...do	.....	4	...do	1	4	2⅛	....	1.50	....	4.00	....	1.875	1.3665	....	
1	...do	...do	.....	4	...do	1	4	2⅛	....	2.58	....	4.58	....	2.955	.7865	....	
1	...do	...do	.....	4	...do	1	4	2⅛	....	.25	....	3.42	....	.625	1.9465	....	
1	...do	...do	.....	4	...do	1	4	2⅛	....	2.17	....	8.25	....	2.545	....	2.8835	
1	...do	...do	.....	4	...do	1	4	2⅛	....	3.58	....	8.25	....	3.955	....	2.8835	
1	...do	...do	.....	4	...do	1	4	2⅛	....	2.33	....	13.83	....	2.705	....	8.4635	
1	...do	...do	.....	4	...do	1	4	2⅛	.83	....	.17	....	0.455	....	5.5365	....	
1	...do	...do	.....	4	...do	1	4	2⅛	1.33	....	....	.17	.955	....	5.1965	....	
1	...do	...do	.....	4	...do	1	4	2⅛	1.50	....	....	.67	1.125	....	4.6965	....	
1	...do	...do	.....	4	...do	1	4	2⅛	.25	....	....	4.50	....	.125	.8665	....	
1	...do	...do	.....	4	...do	1	4	2⅛	.33	....	....	5.83	....	.045	....	.4635	
1	...do	...do	.....	4	...do	1	4	2⅛	1.58	....	....	5.83	1.205	....	....	.4635	
1	...do	...do	.....	4	...do	1	4	2⅛	4.17	....	....	5.92	3.975	....	....	.5535	
1	...do	...do	.....	4	...do	1	4	2⅛	1.08	....	....	9.50	.705	....	....	4.1335	
1	...do	...do	.....	4	...do	1	4	2⅛	1.92	....	....	9.33	1.545	....	....	3.9635	
1	...do	...do	.....	4	...do	1	4	2⅛	2.67	....	....	7.75	2.295	....	....	2.3835	
1	...do	...do	.....	4	...do	1	4	2⅛	4.25	....	....	8.17	3.875	....	....	2.8035	
1	...do	...do	.....	4	...do	1	4	2⅛	5.00	....	....	6.67	4.625	....	....	1.3035	
22	Total								24.91	17.41	1.34	108.67	20.580	20.580	30.2985	30.2985	
									7.50÷20=.375		107.33÷20=5.3665		41.16÷20=2.058		60.5970÷20=3.02985		

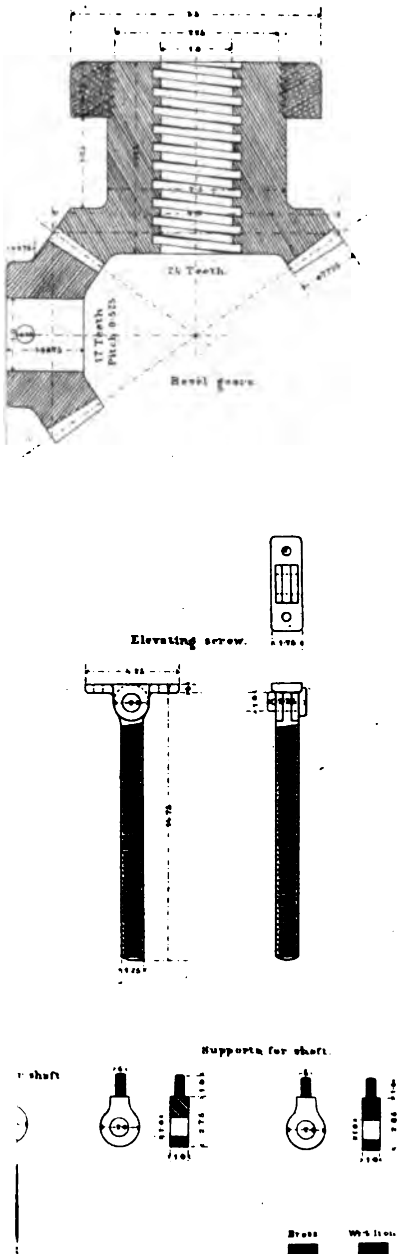


FLANK DEFENCE CARRIAGE

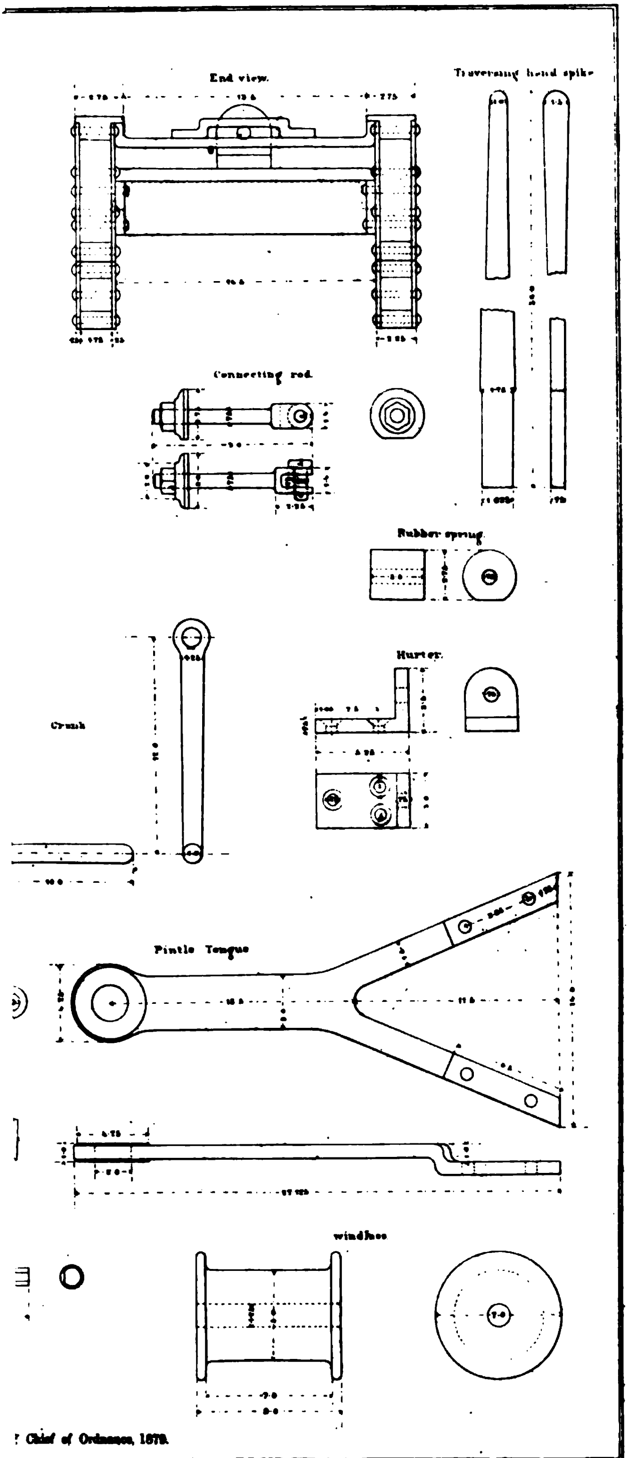
FOR

HOTCHKISS REVOLVING CANNON CAL 1.5.inch.

Scale.



Ordnance, 1879.



: Chief of Ordnance, 1879.

PLATE IV.

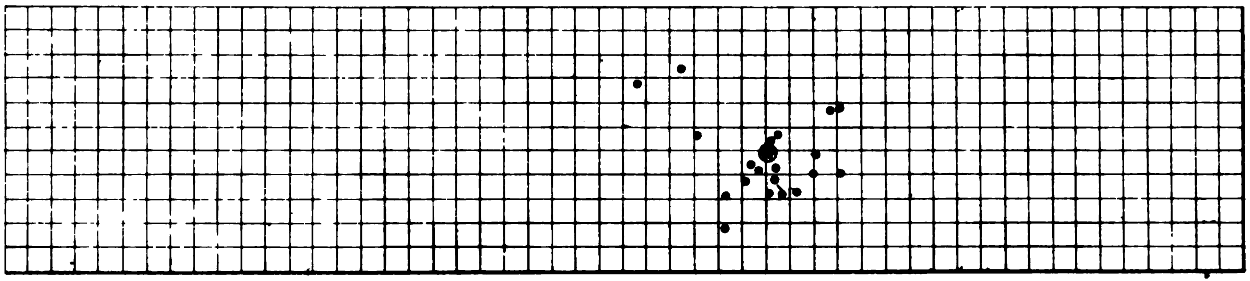
TARGET RECORD OF HOTCHKISS' REVOLVING CANNON, CAL. 1½ INCH.

At Sandy Hook, N. J., April 9th, 1879.

Target 500 Yards from Gun.

Gun mounted on Flank-Defence Carriage.

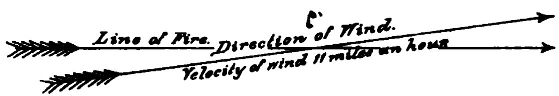
Number of Rounds Fired, 20. *Number of direct Hits in Target, 20.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.)

● *Center of Impact.*

Mean vertical deviation from center of impact .... 1.408 feet.
Mean horizontal deviation from center of impact ... 1.611 "
Mean deviation from center of impact .... 2.139 "



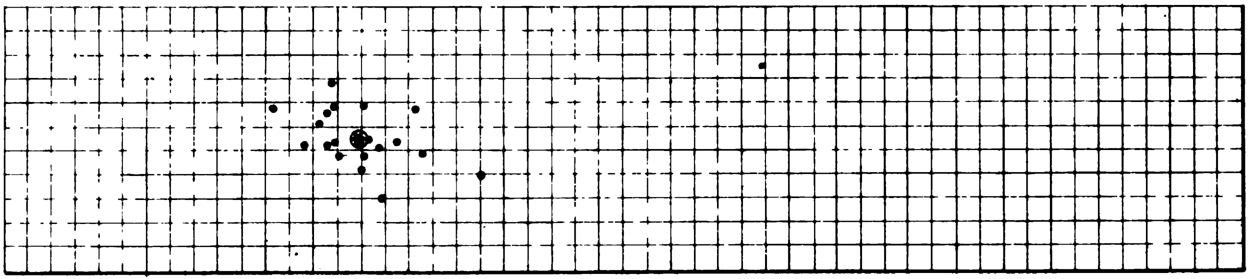
TARGET RECORD OF HOTCHKISS' REVOLVING CANNON, CAL. 1½ INCH.

At Sandy Hook, N. J., April 9th, 1879.

Target 500 Yards from Gun.

Gun mounted on Field Carriage.

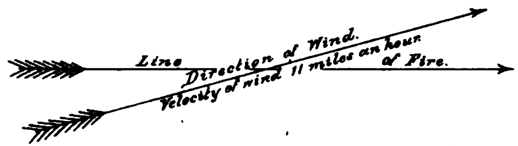
Number of Rounds Fired, 20. *Number of direct Hits in Target, 20.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.)

● *Center of Impact.*

Mean vertical deviation from center of impact .... .985 feet.
Mean horizontal deviation from center of impact ... 1.428 „
Mean deviation from center of impact .... 1.734 „



TARGET RECORD OF HOTCHKISS' REVOLVING CANNON, CAL. 1½ INCH.

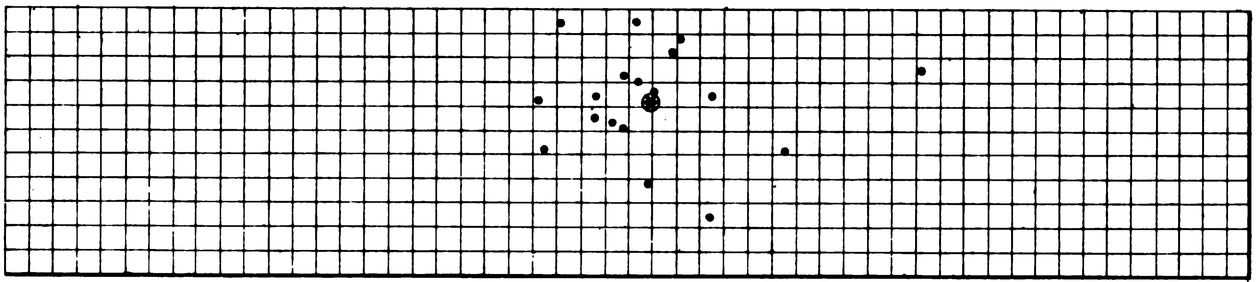
At Sandy Hook, N J., April 16th, 1879.

Target 1,000 Yards from Gun.

Gun mounted on Flank-Defence Carriage.

Number of Rounds Fired, 20.

Number of direct Hits in Target, 18.



Target 11 × 52 Feet. Made of 1 inch Pine Boards.

Center of Impact.

Mean vertical deviation from center of impact .... 1.66694 ft.
Mean horizontal deviation from center of impact ... 2.6355 + " "
Mean deviation from center of impact .... 3.1197 + " "

Line of Fire.

Direction of Wind.

Velocity of Wind 14 miles an hour

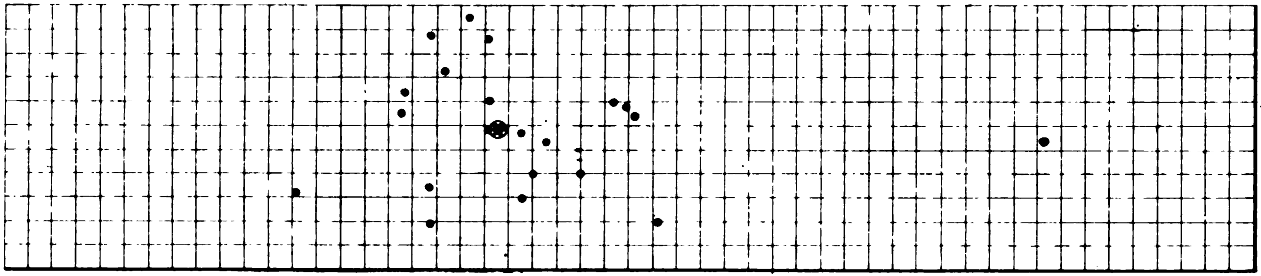
TARGET RECORD OF HOTCHKISS' REVOLVING CANNON, CAL. 1½ INCH.

At Sandy Hook, N J., April 16th, 1879.

Target 1,000 Yards from Gun.

Gun mounted on Field Carriage.

Number of Rounds Fired, 20. *Number of direct Hits in Target, 20.*



Target 11 × 52 Feet. Made of 1 inch Pine Boards.

⊛ *Center of Impact.*

Mean deviation from center of impact .... 3.70416 feet.
Mean vertical deviation from center of impact ... 2.058 .... "
Mean horizontal ..... *do* ..... " ..... " ..... " ..... " ...... 3.02985 .. "

Line of Fire.

Direction of Wind.
Wind 14 miles an hour.

APPENDIX I[6].

RELATIVE DESTRUCTIVE EFFECTS OF DIFFERENT HOTCHKISS PROJECTILES.

(Three plates.)

DESCRIPTION OF SHELLS.

(See Plate I.)

Triple-wall shell, Fig. 1.

This shell has three walls, parallel, or nearly so, with each other, and united to a solid base. In producing it, the inner wall *a* is first cast by the ordinary process. This wall is then suspended upon a core piece, whose dimensions are such as will leave a space between its exterior and the interior surface of the wall *a* equal to the thickness desired for the inner wall *b*. This core and the wall *a* are then suspended in a mold of the common construction, which mold has an inner contour of the shape of the exterior of the complete shell. The metal poured into this mold envelops the inner wall *a* and forms the shell as shown in Fig. 1. The object of this peculiar form of construction is to produce a shell which will be broken into a larger number of pieces than shells of the ordinary construction. Near the forward and rear ends of the cylindrical portion of the shell cannelures are turned to receive the packing or soft brass bands, which are pressed and crimped into place. The base of the shell is slightly chamfered.

Hotchkiss field-shell (ordinary pattern), Fig. 2.

These shells are about an inch longer than those described above, and have greater powder capacity. They are cast in the usual way for casting shells, and have the same general shape as the triple-wall shells. The packing as originally made consisted of a soft brass tubing about 4 inches in length, running nearly two-thirds the length of the cylindrical portion of the shell; it was pressed and crimped into a recess turned on the shell to receive it. Cannelures were turned on the exterior of the tubing to diminish the bearing portion of the packing to be cut through by the rifling of the gun. Before these shell were fired, and to insure suitable rotation, Mr. Hotchkiss added a smooth brass tubing about $1\frac{1}{4}$ inches long, which was pressed and crimped into the recess turned for it. In turning this recess two annular rings were left, as is shown in drawing.

Results of firing at Sandy Hook.

(Plates II and III.)

On the 12th of March 29 rounds, in all, of the triple-wall shells were fired from the Hotchkiss 8^{cm} field-gun at a target 11 by 52 feet, made of 1-inch spruce boards. The first 9 rounds were necessary to get the

proper elevation to allow the projectile to strike about 25 paces in front of the target, previous experiments, with shell of all kinds, having shown that projectiles exploding at this distance produce the most destructive effect upon the target; of these 9 fired, one burst at muzzle of gun. The remaining 20 rounds produced the following results: Total hits 348, of which 300 went through the target; 1 shell burst at muzzle of gun. Average hits, per shot, 17.4.

Firings with the ordinary shell manufactured by Mr. Hotchkiss for the 8^{cm} gun were made on the 19th following, under the same conditions of target, elevation, powder, &c.; no preliminary shots were necessary, the proper elevation having been ascertained by the experiments of the 12th. Twenty shots fired gave results as follows: 209 total hits, with 185 pieces through target; 2 of the shells burst at muzzle of the gun. Average hits, per shot, 10.45.

CONCLUSIONS.

An examination of the results of firing and accompanying targets show an average of 17.4 hits per shot for the triple-wall against 10.4 for the common shells. The liability to premature explosion or breaking up in the gun seems to be about as great for one as for the other.

These trials having demonstrated the superior destructive effects of the triple-wall over the common shells, the Board recommends that further experiments be made to more fully test their merits, when funds are available for the purpose.

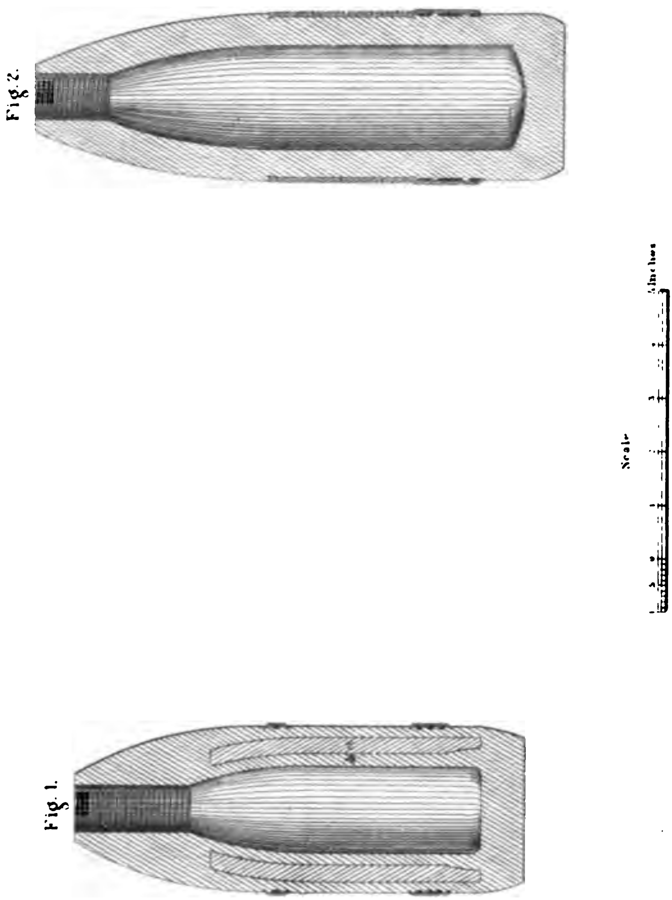
Target record of firing with 3″.15 (8 centimeters) Hotchkiss breech-loading rifle, at Sandy Hook, New York Harbor, from March 12, 1879, to March 19, 1879.

Number of fire.	Time.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Elevation in degrees.	Bursting charge.	Kind of cartridge case.	Kind of fuze.		
	1879.		lbs. oz.		lbs. oz.		oz.			Fired at 500-yard target—	
31	Mar. 12	New mortar	2 8	Hotchkiss triple-wall shell.	12 8	......	4½	Brass	Hotchkiss percussion.	Direct hit, 4′ left, 5′ above. Burst on striking ground 150 yards in rear.	
32	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Direct hit, 3′ left, 1½′ above. Burst on striking ground 100 yards in rear.	
33	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Direct hit, 2′ right, 3½′ below. Burst on striking ground 50 yards in rear.	
34	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 61 paces in front of target.	
35	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 50 paces in front of target.	
36	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Direct hit, 2′ right, 3′ below. Burst on striking ground 30 paces in rear.	
37	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst at muzzle.	
38	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 10 paces in front.	
39	..do	..do	2 8	..do	12 8	......	4½	Tin	..do	Burst on striking ground 65 paces in front.	
40	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 10 paces in front	Target plotted for rounds 40 to 59, inclusive.
41	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Direct hit. Burst on striking ground beyond.	Total number of hits in target 348
42	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	..do	Pieces through 300
43	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 50 paces in front of target.	Pieces not through. 48
44	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 30 paces in front of target.	Target 11′ x 52′, made of 1″ spruce boards.
45	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst at muzzle	
46	..do	..do	2 8	..do	12 8	−¼	4½	do	..do	Burst on striking ground 55 paces in front of target.	
47	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 40 paces in front of target.	
48	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 20 paces in front of target.	
49	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 40 paces in front of target.	
50	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 25 paces in front of target.	
51	..do	..do	2 8	..do	12 8	−¼	4½	..do	..do	Burst on striking ground 40 paces in front of target.	
52	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 20 paces in front of target.	
53	..do	..do	2 8	..do	12 8	......	4½	..do	..do	..do	
54	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 65 paces in front of target.	
55	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 40 paces in front of target.	
56	..do	..do	2 8	..do	12 8	......	4½	..do	..do	..do	
57	..do	..do	2 8	..do	12 8	......	4½	..do	..do	..do	
58	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 50 paces in front of target.	
59	..do	..do	2 8	..do	12 8	......	4½	..do	..do	Burst on striking ground 30 paces in front of target.	

Target record of firing with 3′.15 (8 centimeters) Hotchkiss breech-loading rifle, &c.—Continued.

Number of fire.	Time.	Powder.		Projectile.		Elevation in degrees.	Bursting charge.	Kind of cartridge case.	Kind of fuze.		
		Kind.	Weight.	Kind.	Weight.						
	1879.		*lbs. oz.*		*lbs. oz.*		*oz.*				
60	Mar. 19	New mortar	2 8	Hotchkiss shell, altered by brass band.	12 4	−¼	11½	Brass	Hotchkiss percussion.	Struck ground 25 paces in front of target and burst.	Target plotted for rounds 60 to 79, inclusive. Total number of hits in target .... 209. Pieces through .... 195. Pieces not through. 14. Target 11′ x 52′, made of 1″ spruce boards.
61	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 10 paces in front of target and burst.	
62	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 17 paces in front of target and burst.	
63	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 40 paces in front of target and burst.	
64	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 50 paces in front of target and burst.	
65	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 20 paces in front of target and burst.	
66	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Direct hit. Struck ground and burst in air about 300 yards beyond.	
67	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Burst at muzzle	
68	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 5 paces in front of target and burst.	
69	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Burst at muzzle	
70	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 8 paces in front of target and burst.	
71	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	......do	
72	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 10 paces in front of target and burst.	
73	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 15 paces in front of target and burst.	
74	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 16 paces in front of target and burst.	
75	...do	...do	2 8	...do	12 4	−¼	11½	..de	...do	Direct hit. Burst on striking ground 20 paces in rear.	
76	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 10 paces in front of target and burst	
77	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 25 paces in front of target and burst.	
78	...do	...do	2 8	...do	12 4	−¼	11½	..do	...do	Struck ground 25 paces in front of target, ricochetted through, and burst, striking ground beyond.	
79	...do	...do	2 8	...do	12 4	¼	11½	..do	...do	Struck ground 18 paces in front of target and burst.	

HOTCHKISS SHELL FOR HIS 8 c/m (3·15 in) B. L. RIFLE.

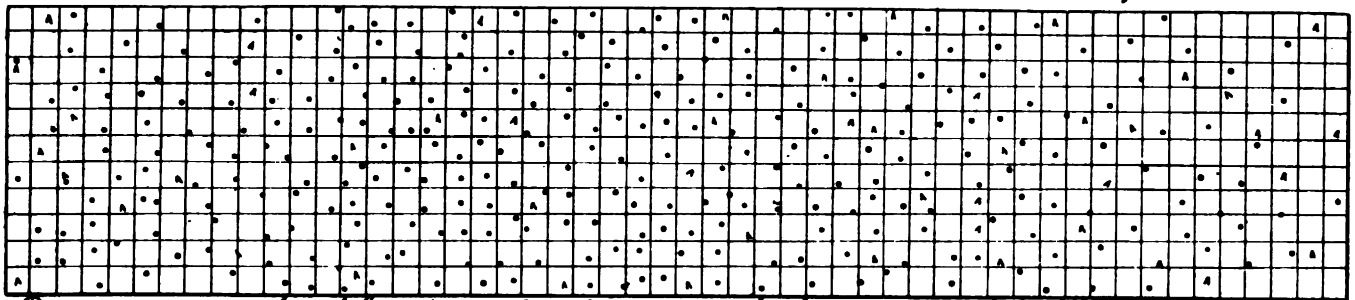


Target Record of 8 c/m (3.15 in) Hotchkiss B. L. Rifle Using triple wall shell

At Sandy Hook N. J. March 12th 1879

Target 500 Yards from gun

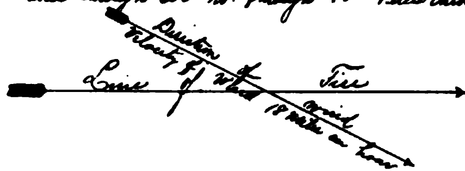
Number of shell fired 70 Total number of hits on target 348



Target 11' x 52' Made of 1 inch Spruce boards Pieces through 300 Not through 48 – Pieces through marked • Not through ▲

1 – Burst at muzzle

2 – Direct hits Bursting beyond target



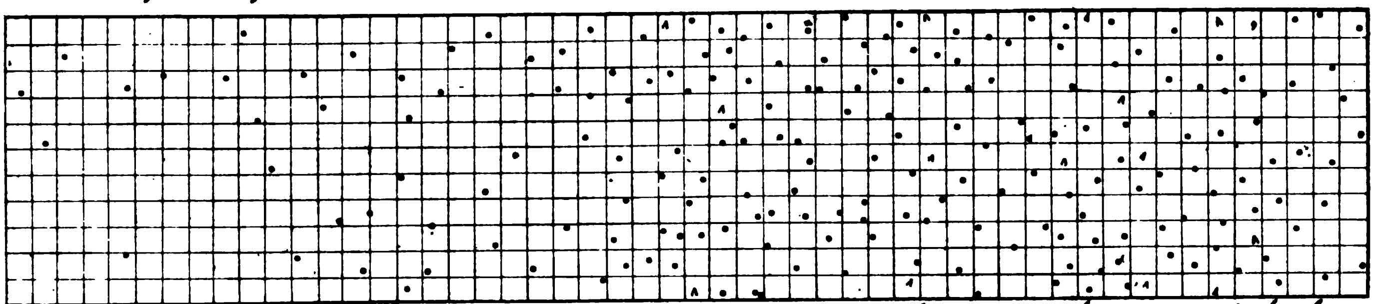
Target Record of 8c/m (3.15in) Hotchkiss B. L. Rifle Using Hotchkiss shell

At Sandy Hook N.J. March 19th 1879

Target 500 yards from gun

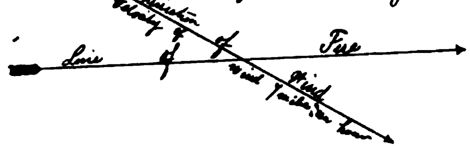
Number of shell fired 90

Total number of hits in target 209



Target 11' x 52' Made of 1 inch Spruce boards

Pieces through 195, Not through 14 - Pieces through marked ● Not through ▲



2 direct hits
3 burst at muzzle
1 ricochet through bursting beyond

APPENDIX I'.

REPORT ON HOTCHKISS REVOLVING CANNON (LIGHT FIELD MODEL, CAL. 1.5 INCH.

(Eight plates.)

DESCRIPTION OF GUN AND CARRIAGE.

(See Plates I, II, III, and IV.)

The gun and carriage differ from those described in the report of the Board of June 18, 1877 (Report of the Chief of Ordnance for 1877, page 609), in minor details only; the principles of construction are the same; the gun and carriage are lighter, and the barrels of the gun shorter. The ammunition also is lighter and shorter than that used in the heavier model, but is alike in all other particulars.

The principal weights and dimensions are given below:

Gun.

Total length of bore .... inches..	$29\frac{1}{8}$
Weight of gun .... pounds (225 kilos.)..	496

Shell.—(See Plate V.)

Length of body .... inches..	3.261
Entire length with fuse .... inches..	3.678
Weight of shell empty .... ounces..	13.19
Weight of fuse .... ounces..	1.92
Weight of bursting charge .... ounce..	0.72
Total weight of projectile complete for firing .... ounces..	15.83

Cartridge case.—(See Plate V.)

Length of case .... inches..	3.711
Weight of case .... ounces..	3.08

Charge of powder.

Charge .... ounces..	2.63
Weight of complete cartridge .... ounces..	21.57
Length of complete cartridge .... inches..	6.57

Carriage.

Weight of .... pounds..	643

RESULTS OF FIRING.

On the 8th and 9th of May, 1879, there were fired from this gun, at Sandy Hook, in all, 170 rounds, of which 4 were for velocity, 76 fired testing workings of gun, 15 sighting shots at the different ranges, and 75 (25 each) at targets 200, 500, 1,000 yards distant. The targets, 11 by 52 feet, were made of 1-inch spruce boards, of which there were three at each range, they being 50 feet apart; 2.63 ounces of new mortar powder was used as the propelling charge, with which an average velocity of 1,161 feet per second was obtained.

The following results were obtained at the different ranges fired:

200 *yards.*—(See Plate VI.)

Shots fired, 25. Total hits, 3 targets, 411.

Total hits:	1st target......	361;	of which	495 were through, and	166	not through.
Total hits:	2d target......	40;	of which	20 were through, and	20	not through.
Total hits:	3d target......	10;	of which	5 were through, and	5	not through.
		411		220	191	

500 *yards.*—(See Plate VII.)

Shots fired, 25. Total hits, 3 targets, 276.

Total hits:	1st target...	91.	Through..	46.	Not through..	41.	Direct hits..	4
Total hits:	2d target...	126.	Through..	42.	Not through..	82.	Direct hits..	2
Total hits:	3d target...	59.	Through..	13.	Not through..	44.	Direct hits..	2
		276		101		167		8

1,000 *yards.*—(See Plate VIII.)

Shots fired, 25. Total hits, 3 targets, 234.

Total hits:	1st target...	189.	Through..	112.	Not through..	71.	Direct hits..	6
Total hits:	2d target...	31.	Through..	8.	Not through..	23.	Direct hits..	0
Total hits:	3d target...	14.	Through..	4.	Not through..	10.	Direct hits..	0
		234		124		104		6

CONCLUSIONS.

These results, rivaling in effectiveness the accuracy, rapidity, and continuousness of fire and wide-spread dispersion of the shell fragments, attained with the heavier models, heretofore tried, of the revolving cannon (at the same range), afford evidence of the entire practicability of the introduction into service of lighter-built guns. This feature will secure that increased mobility in action and easements in transportation so essential for the lighter uses to which it may be desirable, in a varying service, to employ this arm, now probably to take its place as an important adjunct in the service of modern armies.

As an artillery arm for our national militia organizations, for duties which they are sometimes called upon to perform in times of national peace, the defense of property from mob violence, it has (it is believed), at present, no superior.

APPENDIX.

Extract from the report of the Artillery Commission of the Russian Imperial Marine, relative to experiments made with Hotchkiss revolving cannon. (*Nov.* 19, 1878. *No.* 10.)

[Translated from the French by Capt. F. H. Phipps, Ordnance Department.]

The commission, after having described in detail the construction, the mechanism, and the workings of the piece, concludes its report with the following *resumé* of the results of their experiments:

1st. Facility of manoeuver.

The manoeuver of this cannon is as easy as convenient. The employment of the butt piece, and the particular construction of the sight, permit the piece to be directed as a small-arm and sighted as easily as though firing off-hand, conditions very important for rapidity of fire. The same gunner points the piece, changes freely

its direction, and delivers the shot; a single assistant is necessary for feeding. The commission thinks, however, that a certain habit of duty with the piece is indispensable to the man who points; rapidity of fire requires that this gunner operates simultaneously the change of direction with the left hand, and the manoeuver of the firing-crank with the right hand, and that without the eye leaving the line of fire.

Relative to the sight, the commission thinks that the sights with fixed graduations are preferable for rapidity of fire, since they obviate the necessity of a new adjustment at each shot. It recognizes at the same time that this advantage involves a cause of error possible in the pointing; fixed graduations might be confounded with each other in rapid changes of the line of fire.

2D. SOLIDITY OF THE MECHANISM.

The mechanism of the Hotchkiss revolving cannon admits of only a small number of parts of considerable dimensions and, rationally combined, presenting every guarantee of solidity.

The commission fired 210 rounds without the mechanism becoming clogged. A single stoppage, which occurred, arose from a mistake of the pyrotechnist.

A cartridge without powder having been introduced into the chamber of the gun, the priming only was fired, and the shell remained in the bore, whilst the cartridge-case was removed by the extractor. The shell prevented the introduction into this barrel of a new projectile and momentarily delayed the firing. This obstacle removed, the mechanism functioned irreproachably.

3D. RAPIDITY OF FIRE.

Each revolution of the crank corresponds to a shot, the velocity of the mechanism attaining 60 to 80 shots a minute. But the rapidity of fire depends upon the promptness with which the arm is fed with cartridges, proving in reality less great.

The experiments of the commission furnished on this point the following results:

A. Firing without pointing 32 shots a minute.

B. Firing at a field target placed at a distance of 200 sagénes of 6 feet (400 yards) from the piece, pointing at each shot, 20 shots a minute, giving 12 hits in the target; proportion of direct hits to shots fired, 60 per cent.

C. In order to determine the rapidity and useful effect of fire against a moving object, ten targets were employed, each one representing the end view of a torpedo boat. These targets, disposed in oblique echelon in order that they might not mark each other, were placed at distances from the gun increasing from 30 sagénes of 6 feet* (60 yards) in such a way that while the first is at 80 sagénes (160 yards) from the cannon the last was $80 + (9 \times 30)$, or 350 sagénes (700 yards) removed.

In order to approach as near as possible to the practical conditions of fire against a torpedo-boat during its attack, a shot was directed successively against each target, commencing at the last and finishing with the first.

A first series of 10 shots fired in 23 seconds gave 4 hits, 1 of which was in the tenth target, 1 in the second, and 2 in the first. The torpedo-boat advancing with the speed of 41.7 knots would receive directly three projectiles in getting over 270 sagénes (540 yards).

A second series of 10 shots was fired in 60 seconds in the same order as those of the first series, giving 3 hits, 1 each in the ninth, fifth, and second targets, corresponding to 3 hits upon a torpedo-boat approaching with a speed of 16.04 knots.

Finally, a third series of 5 shots was fired in 45 seconds, and directed against 5 targets, 60 sagénes apart (120 yards), the first being placed at 80 sagénes (160 yards) from the gun; these shots gave 2 hits in the different targets, corresponding to 2 hits on a torpedo-boat traveling with a speed of 21.4 knots.

4TH. INITIAL VELOCITY OF THE PROJECTILE.

The initial velocity of the cast-iron shell weighing 15.35 ounces, and fired with a charge of 2.9 ounces of cannon-powder, was 1,311 feet. That of the steel shell of 17.2 ounces, fired with the same charge, was 1,228 feet.

5TH. REGULAR FIRE AGAINST METALLIC PLATES.

The following results were obtained in firing against iron plates of ½″ and 1″ thickness, bolted to vertical oak posts.

*NOTE.—The sagéne of 6 feet used in the Russian marine is equal to $1^m 83$ (about 2 English yards), and must not be confounded with the sagéne of 7 feet, which is equal to $2^m 134$ (2⅓ yards), used in the Russian land service.

A. The weighted cast-iron shell penetrated freely the ½-inch iron plate at a distance of three cable-lengths (720 yards). Firing at the same distance against * 1-inch iron plates, the same projectile broke in small pieces in making only an impression.

B. The cast-iron shell loaded went through, at the same distance, the ½-inch iron plate and exploded behind the target. Under the same circumstances this projectile only produced a feeble impression in the 1-inch plate and exploded in front of the target.

C. The weighted steel projectile fired against the 1-inch iron plate made a bulge 2 inches in depth and detached fragments of the target; the hole was through, but the shell did not go through.

D. The steel shell loaded pierced the 1-inch plate and made an indent only ½ inch in depth. The fragments of the projectile fell in front of the target.

6TH. OBLIQUE FIRE AGAINST THE PROW OF A TORPEDO-BOAT AT A DISTANCE OF TWO CABLE-LENGTHS (480 YARDS).

First shot, weighted cast-iron shell.

The projectile struck the left-hand corner on a level with the second bulkhead, starting from the front, passed through the second and third bulkheads, and struck a ½-inch iron plate representing the boiler of the torpedo-boat, upon which it was broken to pieces, slightly damaging the plate.

Second shot, weighted cast-iron shell.

The projectile struck the right-hand corner in front of the first bulkhead, passed through the corner of the first bulkhead, and broke to pieces on a ricochet.

The fragments produced in the second bulkhead four holes and one indentation; in the third three holes and one indentation; and on the ½-inch iron plate three indentations, one of which was ⅜ of an inch deep, the other two being slight.

Third shot, steel shell.

This projectile struck the right-hand corner close to the second bulkhead, penetrating these two bulkheads, ricochetted in deviating to the left, and breaking itself in turning against the ½-inch iron plate, upon which it made an oval indentation ½ inch deep. During this fire the projectile hit the corner of the torpedo-boat under an angle of from 15° to 20°.

7TH. EXPLOSIVE EFFECTS OF THE PROJECTILES.

In order to study the explosive effects of the projectiles loaded and provided with the Desmarest fuse, the fire being directed against two wooden targets of 1-inch spruce, 21 feet long and 3 feet high, placed the first at 600 yards from the piece, and the second 12 feet behind the first. Of the 8 shots fired 4 burst between the two targets, and 4 after having passed through them. There was found on the second target 76 holes, being 19 hits per shot.

8TH. TEST OF THE ACCURACY OF THE PIECE.

Firing for accuracy was made with some cast-iron shells at targets placed at 200, 600, and 1,000 yards distant. The tests were made to determine the mean deviation of these projectiles.

Distances.		Mean deviation.			
		Horizontal.		Vertical.	
Sagénes.	Meters.	Feet.	Meters.	Feet.	Meters.
100	183	0.12	0.0366	0.40	0.122
300	549	0.80	0.244	1.10	0.3355
500	915	1.30	0.3965	1.60	0.488

These deviations are greater by 1''.75 than those from the Engström cannon, but less by 2½ inches than those of the light cannon of Baranowsky.

* An encablure or cable's length is equal to 120 fathoms or 720 feet.—Ordnance Manual, 1861.

CONCLUSIONS.

After the experiments made with the Hotchkiss revolving cannon, the commission recapitulated in the following conclusions its opinion of this arm:

1st. The solidity of the mechanism, the convenience of its management, and the facility with which the piece can be taken apart and put together again are completely satisfactory.

2d. Its ease of manoeuver and rapidity of pointing are very remarkable. On this point the Hotchkiss revolving cannon has an incontestable superiority over all arms of its kind.

3d. The precision of fire of the Hotchkiss revolving cannon is very satisfactory.

4th. With respect to rapidity of fire the Hotchkiss revolving cannon has an advantage over the Engström and Baranowsky cannon.

5th. The pivot of the Hotchkiss revolving cannon presents all the guarantees of solidity

6th. The effect of the loaded shells on the wooden launches was satisfactory. The Desmarest fuses, however, were wanting in sensibility.

7th. The effects of the projectiles on the ½-inch and 1-inch iron plates, and upon the torpedo-boats, were sufficient.

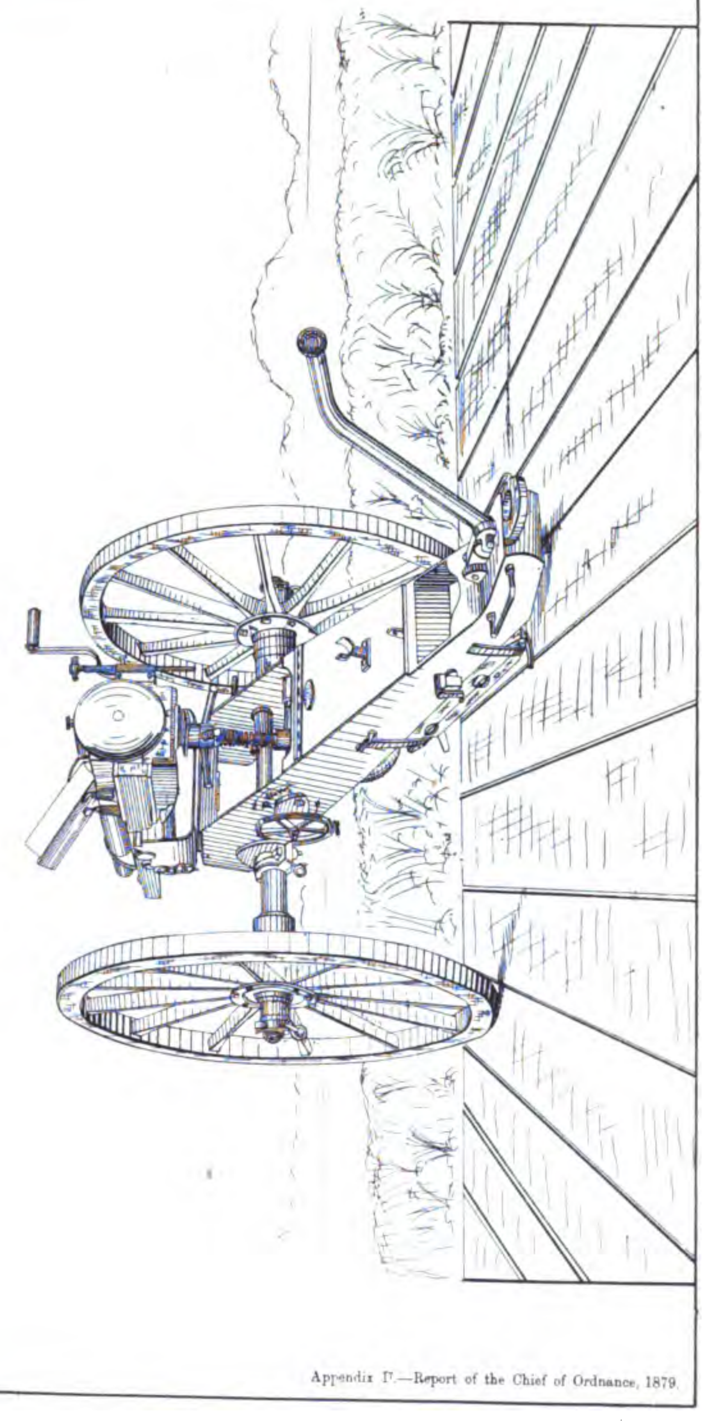
The commission, in view of the preceding conclusions, is of the opinion that the Hotchkiss revolving cannon should find place in the armament of the ships of the Russian imperial navy as a means of defense against torpedo boats.

Target record of firing with Hotchkiss revolving cannon No. 385, at Sandy Hook, N. Y. H., from May 8 to May 9, 1879.

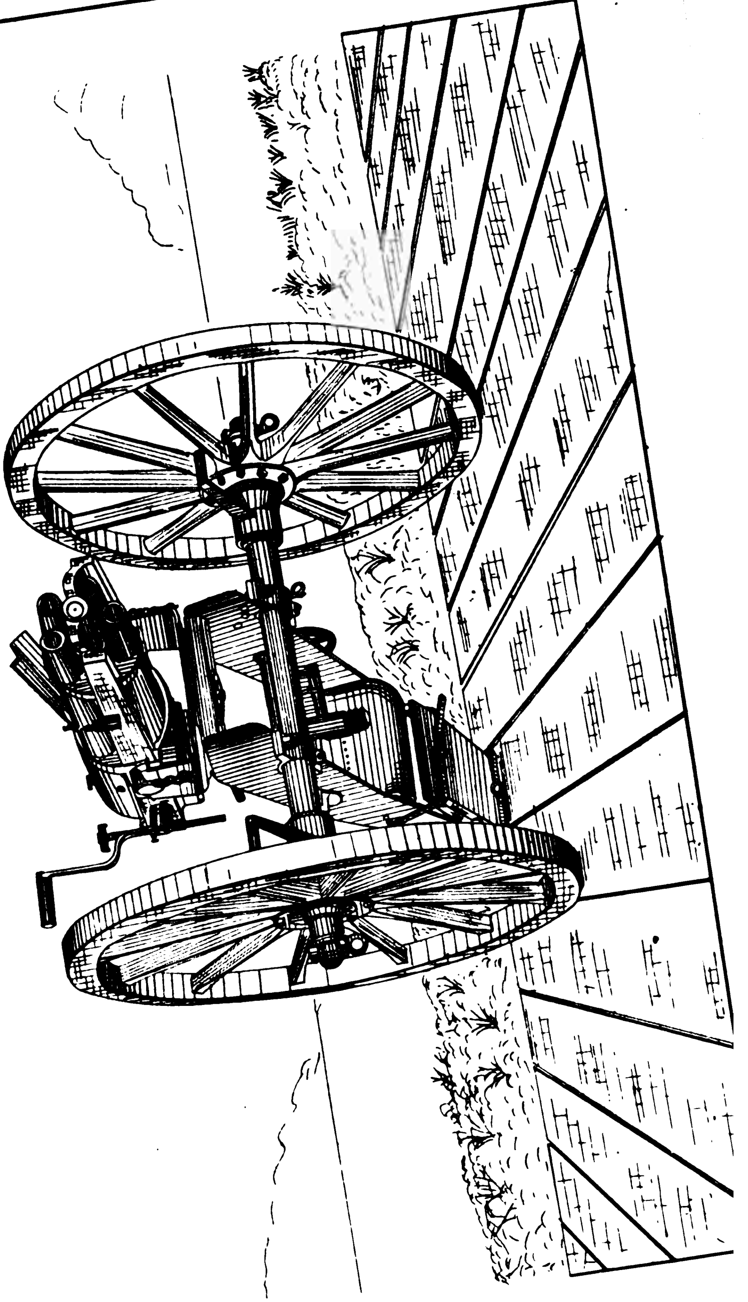
LIGHT FIELD MODEL.

No. of fire.	Time.	Powder. Kind.	Powder. Weight. lbs.	Powder. Weight. oz.	Projectile. Kind.	Projectile. Weight. lbs.	Projectile. Weight. oz.	Elevation in degrees.	Initial velocity, feet.	
	1879.									
8	May 8	New mortar	....	2.6	Hotchkiss	....	15.83	+30′ to −15′	......	Fired at 200-yard target, sighting shots.
25	....do	......do	....	2.6	....do	....	15.83	−15′	......	Fired at 200-yard target, targets 11′ × 52′, made of 1″ spruce boards.
										Three targets in column: 1st target, 200 yards from gun; 2d target, 50′ in rear of 1st; 3d target, 50′ in rear of 2d.
										Total number of hits in—
										1st target, 361; pieces through, 195; pieces not through, 166.
										2d target, 40; pieces through, 20; pieces not through, 20.
										3d target, 10; pieces through, 5; pieces not through, 5.
										Three targets, 411; pieces through, 220; pieces not through, 191.
48	....do	......do	....	2.6	....do	....	15.83	+1°	......	Fired down beach, testing working of gun.
4	....do	......do	....	2.6	....do	....	15.83	....	......	Fired at 1,000-yard target, sighting shots.
25	....do	......do	....	2.6	....do	....	15.83	2¼°	......	Fired at 1,000-yard target, targets 11′ × 52′, made of 1′ spruce boards.
										Three targets in column: 1st target, 1,000 yards from gun; 2d target, 50′ in rear of 1st; 3d target, 50′ in rear of 2d.
										Total number of hits in—
										1st target, 189; pieces through, 112; pieces not through, 71; direct hits, 6.
										2d target, 31; pieces through, 8; pieces not through, 23; direct hits, 0.
										3d target, 14; pieces through, 4; pieces not through, 10; direct hits, 0.
										Three targets, 234; pieces through, 124; pieces not through, 104; direct hits, 6.
28	May 9	......do	....	2.6	....do	....	15.83	....		Fired down beach, testing working of gun.
3	....do	......do	....	2.6	....do	....	15.83	58′	......	Fired at 500-yard target, sighting shots.
25	....do	......do	....	2.6	....do	...	15.83	58′	......	Fired at 400-yard target, targets 52′ × 11′, made of 1″ spruce boards.
										Three targets in column: 1st target, 500 yards from gun; 2d target, 50′ in rear of 1st; 3d target, 50′ in rear of 2d.
										Total number of hits in—
										1st target, 91; pieces through, 46; pieces not through, 41; direct hits, 4.
										2d target, 126; pieces through, 42; pieces not through, 82; direct hits, 2.
										3d target, 59; pieces through, 13; pieces not through, 44; direct hits, 2.
										Three targets, 276; pieces through, 101; pieces not through, 167; direct hits, 8.
1	....do	......do	....	2.6	....do	....	15.83	....	Lost	Fired into sand-butt to try powder.
1	....do	......do	....	2.6	....do	....	15.83	....	1,165	
1	....do	......do	....	2.6	....do	....	15.83	....	1,158	
1	....do	......do	....	2.6	....do	....	15.83	....	1,160	
170										

PLATE I.



Appendix I'.—Report of the Chief of Ordnance, 1879.



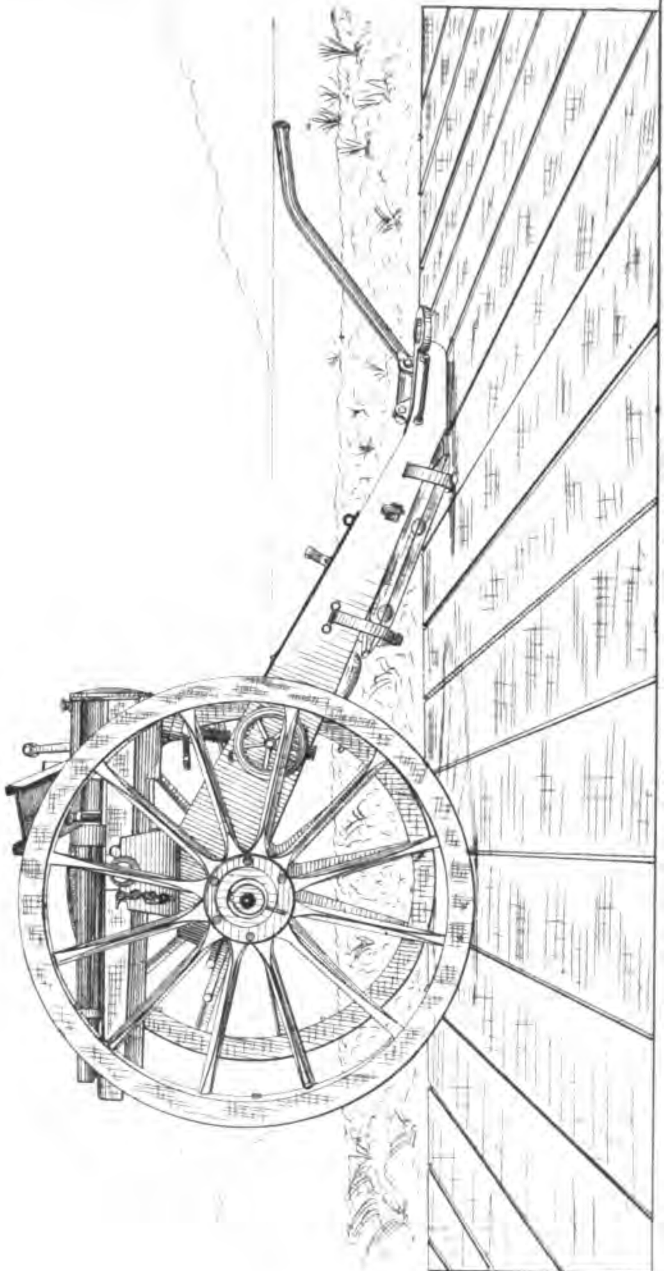
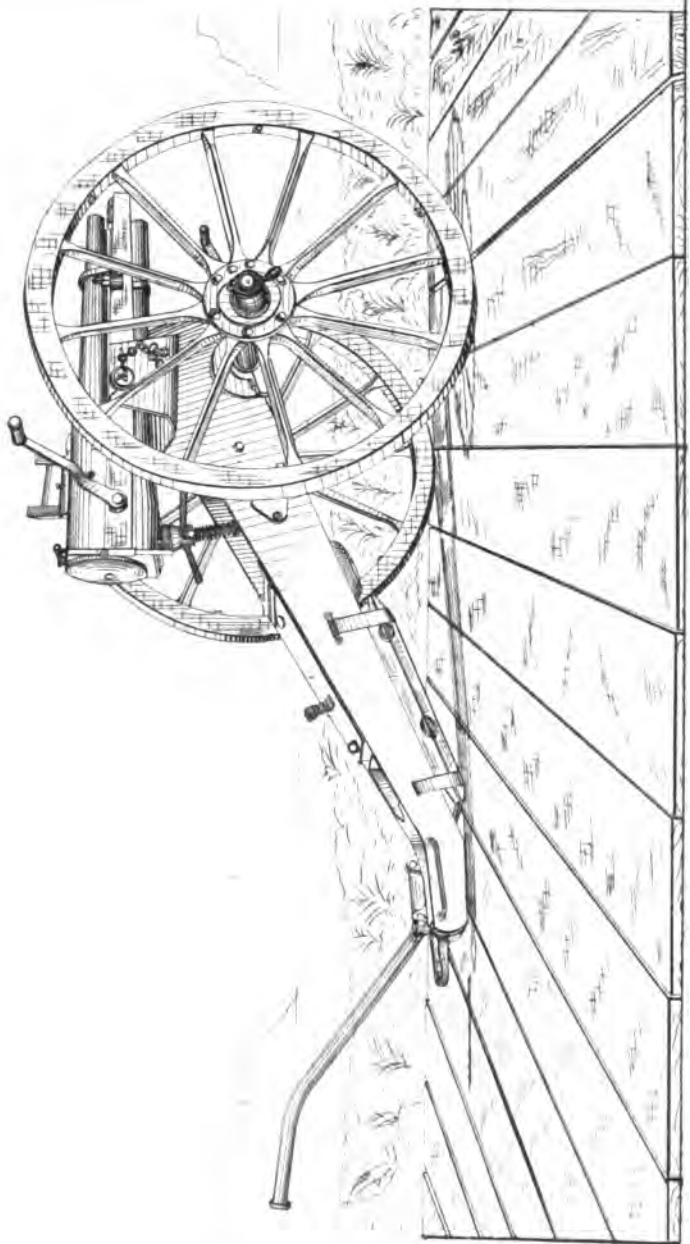
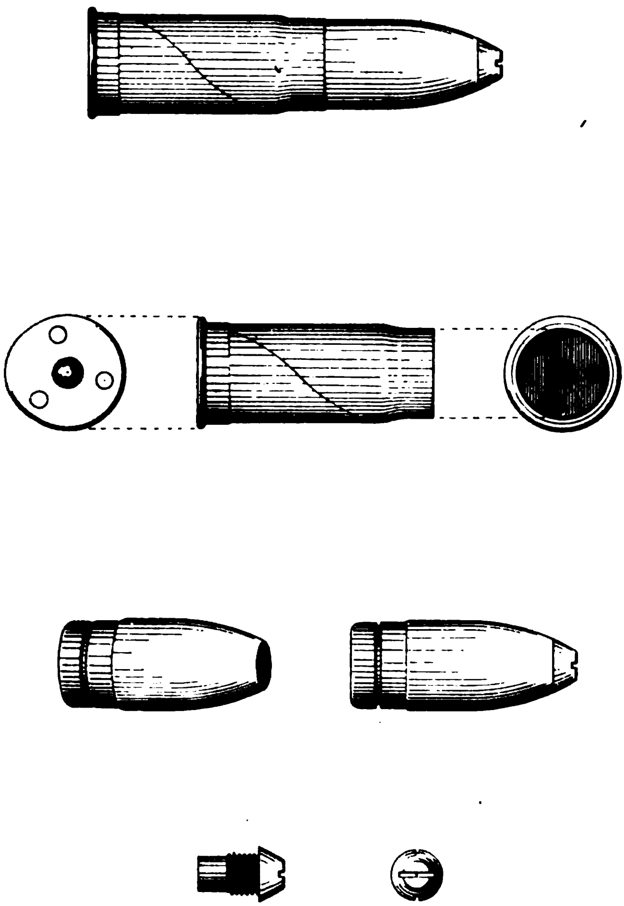


PLATE IV.

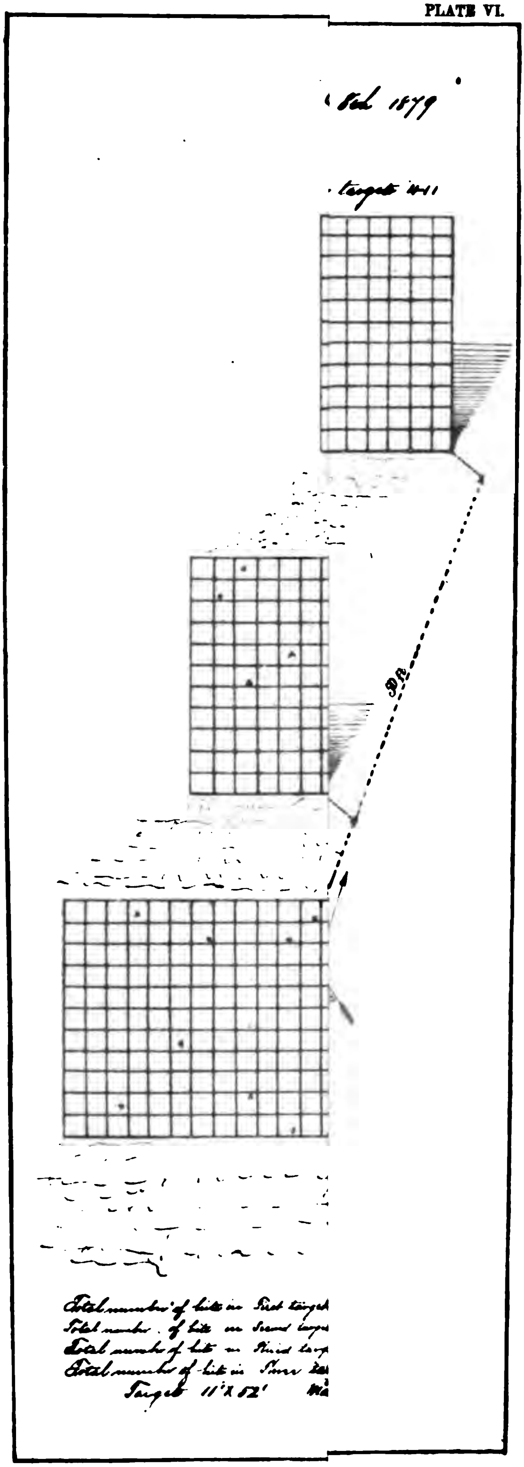


Appendix T.—Report of the Chief of Ordnance, 1879.



Appendix I[7].—Report of Chief of Ordnance, 1879.

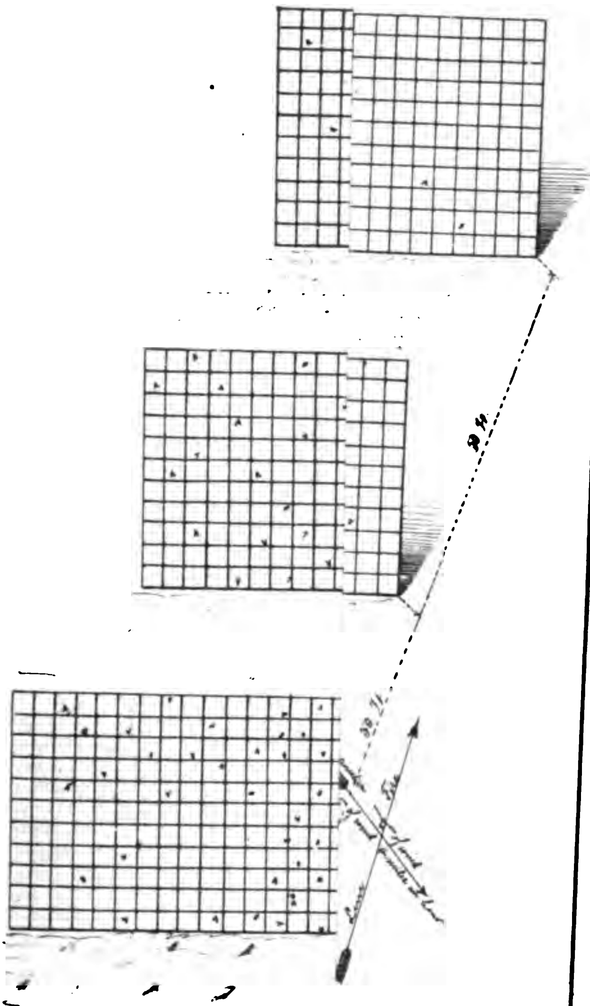
PLATE VI.


1879
Total number of hits in First
Total number of hits in Second
Total number of hits in Third
Total number of hits in
Target 11' x 52'

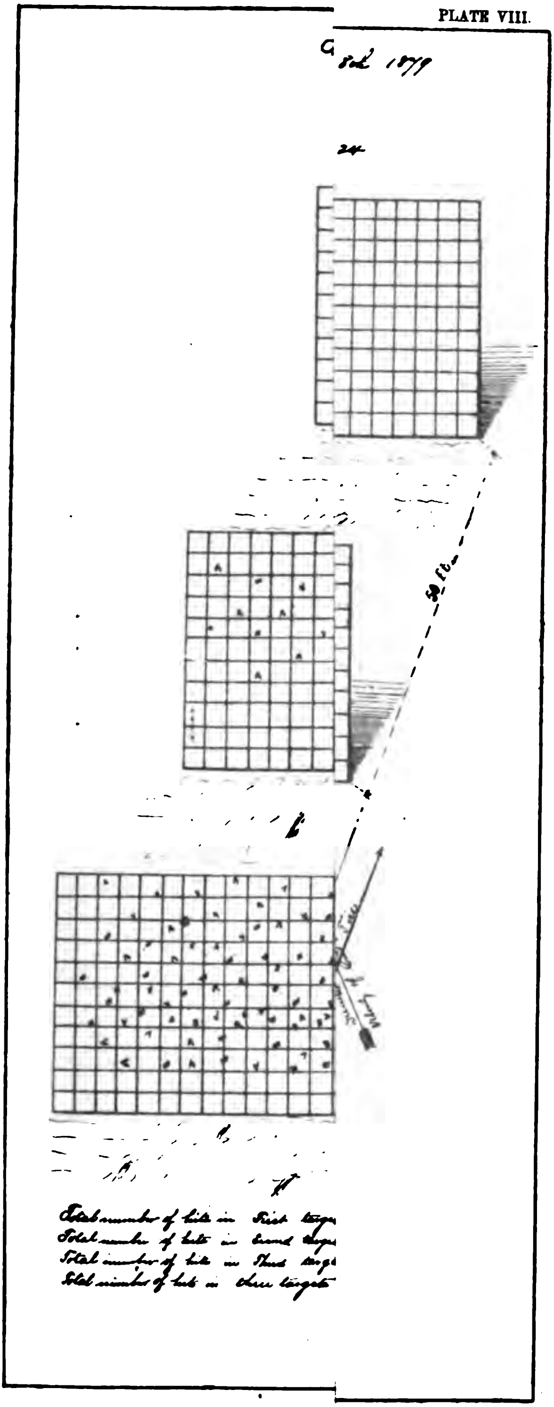
Target 9th 1879

short board)

ste 276



Total number of hits on first target 9
Total number of hits in second target 12
Total number of hits in third target 2
Total number of hits in three targets 2?
Target 11' x 52' Made of on


8th 1879
50 ft.
Total number of hits in First targe
Total number of hits in Second targe
Total number of hits in Third targe
Total number of hits in three targets

APPENDIX I[8].

PROGRESS REPORT ON THE 3-INCH BREECH-LOADING RIFLE.

This gun was altered on the recommendation of the Constructor of Ordnance in his letter of October 12, 1878, and is fully described in his report of October 2, 1879. It was mounted on the ordinary 3-inch field-carriage.

A summary of the results obtained with varying charges of different powders is appended, from which it will be seen that the I. A. powder gave the best results, the pressure being quite low for the velocities obtained.

The breech mechanism worked with facility in every instance, there being in one or two cases a slight escape of gas, but not enough to cause any sticking of breech-block. This system offers an easy and economical method of converting our present muzzle-loading field guns into breech-loaders, and the Board recommends that a battery of these be made for issue, by sections, to batteries in the service for competitive trials with the muzzle-loaders, and that the artillery officers be called upon for an expression of opinion with regard to their relative merits.

AVERAGES.

Results with 3″ breech-loading rifle to determine proper kind and charge of powder for use with 3″ rifles.

No. of rounds.	Powder.				Projectile, Butler.		Pressure, lbs. per square inch of bore.	Velocities at 75′ from muzzle.	Remarks.
	Kind.	Weight of charge.	Density.	Granulation.	Kind.	Weight.			
		Lbs.				*Lbs.*			
4	E. Z.......	1¼	......	25888	Butler cored shot.	10½	11, 500	976	
8	"	1½	......	"	....do	10½	14, 928	1, 074	
3	"	2	......	"	....do	10½	30, 666	1, 262	
3	"	2¼	......	"	....do	10½	59, 000	1, 422	
2	E. Z. A....	2⅛	1. 750	31232	....do	10½	45, 750	1, 415	
2	I. A.......	2¼	"	2200	....do	10½	21, 250	1, 387	
4	"	2¾	"	"	....do	10½	24, 000	1, 459	
4	"	3	"	"	....do	10½	36, 333	1, 542	
3	E. Z.......	2	"	"	....do	10½	....	....	Fired over water. Smooth flight.

APPENDIX I[9].

PROGRESS REPORT ON 3.17-INCH MUZZLE-LOADING RIFLE, CHAMBERED GUN.

For full description of the construction of this gun, see report of the Constructor of Ordnance.

CARRIAGE.

The extra width at the breech, due to the banding of this gun, prevented its being mounted on an ordinary field-carriage; one for the $4\frac{1}{2}''$ siege-rifle was therefore adapted to its use.

POWDER.

With the exception of two rounds of Du Pont's hexagonal I. C. powder, the density and granulation of which were respectively 1.7 and 72; Du Pont's sphero-hexagonal I. B. powder, having a density of 1.728 and a granulation of 123, was employed. The charge of powder used in all the tests being longer than the chamber of the gun, it was necessary, in order that the powder might be forced into place, to rip the longitudinal seam in the bag, with the exception of about 2 inches at each end, and to substitute for the thread a steel wire; the cartridge being forced down, and the wire removed by means of a string attached to it, the powder lying beyond was forced loosely into the chamber. The charges of powder varied from $5\frac{5}{16}$ to $5\frac{15}{16}$ pounds; the resulting air-space ranging from 31.32 to 35 cubic inches per pound of powder.

PROJECTILES.

The projectiles were all of the Butler pattern, and, except two, $12\frac{1}{2}$ pounds solid shot, and five $11\frac{1}{2}$ pound cored shot—the latter fired at sea for ranges—were cored shot, weighing $10\frac{1}{2}$ pounds.

RESULTS OF FIRING.

An examination of the record of firing appended shows that the best results were obtained with 5 pounds 13 ounces of I. B. powder, which gave a muzzle velocity of 2,026 feet with only 30,000 pounds pressure. The loss of 37 feet in velocity in 81 feet of flight, though great, might be expected of a light projectile moving with such very great velocity. It will also be observed that an increase in the charge of powder, 2 ounces, gave no additional velocity to the projectile, fixing 5 pounds 13 ounces as the maximum effective charge of this powder for this rifle. The best average results so far obtained from the 3″ breech-loading rifle was with 3 pounds of I. A. powder, using same kind and weight of projectile as above, the resulting muzzle velocity being 1,558 feet, and pressure 36,333 pounds. The loss of velocity in 75 feet was 16 feet. An average of five rounds with the chambered rifle gave a range of 3,049 yards.

CONCLUSIONS.

It will be seen that the advantage of chambering is fully established, as the results obtained are most excellent, and fully equal to any developed abroad. It is therefore of the highest importance, in the opinion of the Board, that further experiments be made by applying this principle to higher calibers, and practically establishing the extent to which it can be used in our sea-coast armament.

After a full consideration of the subject, as applied to our present field guns, the Board is of the opinion that the chambering principle should be used in any which may hereafter be altered into breech-loaders.

AVERAGES.

Record of firing with 3''.17 chambered rifle at Sandy Hook, New York Harbor.

Number of rounds.	Date of firing.	Powder. Kind.	Powder. Weight of charge.	Projectiles. Kind.	Projectiles. Weight.	Elevation, degrees.	Velocities at 81' from muzzle.	Pressures pounds per □'' of bore.	Length of projectile, in calibers.	Cubic inches of air space per pound of powder.	Remarks.
	1879.		*Lbs.*		*Lbs.*						
2	Sept. 10 and 11	Du Pont's sphero-hexagonal I. B. Density, 1.728; granulation, 123.	[illegible]	Butler cored shot	[illegible]	0	1,860	22,500	[illegible]	35	
2	Sept. 11	do	[illegible]	do	[illegible]	0	1,914	24,500	[illegible]	34	
2	do	do	[illegible]	do	[illegible]	0	1,946	26,750	[illegible]	33	
2	do	do	[illegible]	do	[illegible]	0	1,993	30,000	[illegible]	32	Calculated muzzle velocity, 2,026 feet.
2	do	Du Pont's hexagonal I. C. Density, 1.70; granulation, 72.	[illegible]	do	[illegible]	0	1,881	23,250	[illegible]	34	
2	do	Du Pont's sphero-hexagonal I. B. Density, 1.728; granulation, 123.	[illegible]	Butler solid shot	[illegible]	0	1,875	31,000	[illegible]	34	
1	do	do	[illegible]	Butler cored shot	[illegible]	0	1,990	28,500	[illegible]	31.66	
1	do	do	[illegible]	do	[illegible]	0	1,993	....	[illegible]	31.32	
5	Sept. 17	do	[illegible]	do	[illegible]	5	....	....	[illegible]	32	Fired out to sea for ranges. Average range, 3,049½ yards.
19											

APPENDIX I[10].

PROGRESS REPORT ON 8-INCH BREECH-LOADING RIFLE.

The gun and carriage were fully described in the report of the Constructor of Ordnance, and published in the Report of the Chief of Ordnance for 1878.

This rifle has been fired in all 202 rounds, 190 of which were with battering charges (35 pounds). An examination of the accompanying record will show that in the firings with battering charges the average weight of shot used was 181 pounds; the mean velocity at muzzle, 1,363 feet; the mean maximum pressure, 30,302 pounds per square inch of bore; and the mean energy at muzzle, 2,333 foot-tons.

REMARKS.

The gun remains, so far, intact, and awaits the trials further contemplated and decided upon as necessary to test the endurance of this system of construction.

AVERAGES.

TABLE No. 1.—*Record of firings for endurance with an experimental 8″ breech-loading rifle, from August 1, 1878, to August 27, 1879, inclusive, at Sandy Hook, New York Harbor.*

Description of gun.	Date.	Number of shots.	Charge. Kind of powder.	Charge. Cartridge. Weight.	Charge. Cartridge. Height.	Charge. Cartridge. Diameter.	Projectile. Kind.	Projectile. Weight.	Projectile. Diameter.	Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulangé's chronograph.	Velocities at the muzzle.	Energy of projectile. Total at the muzzle. $\frac{WV^2}{2g\,2240}$	Energy of projectile. Per inch of shot's circumference. $\frac{WV^2}{4g\pi R\,2240}$	Gas pressure per square inch of bore, as taken with Rodman's internal pressure gauge.
				Lbs.	In.	In.		Lbs.	In.	Feet.	Feet.	Ft. tons.	Foot-tons.	Pounds.
An 8-inch breech-loading rifle converted from a 10-inch Rodman smooth-bore by lining with a steel-jacketed coiled wrought-iron tube, inserted from the breech; jacket of the tube being prolonged to the rear and adapted for reception of the round wedge fermeture. Caliber, 8 inches. Total length of gun, 147.25 inches. Length of rifled portion of bore, including bevel, 101.25 inches. Length of chamber, 22 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15 each. Twist uniform, one turn in forty feet. Weight of gun. 17,075 pounds.	August 8 and 17, and December 5, 1878	1	Du Pont's hexagonal F. P. B. Density, 1.785; granulation, 67.	*25	16¼	7.25	Butler.	185	7.95	....	....	....	....	15,500
		1		*30	19¼	7.25	..do ...	183	7.95	....	..	....	....	24,500
		1		*30	19¼	7.25	..do ...	186	7.95	1,331	1,338	2,308	92.40	29,500
	October 17, 1878	1		35	22¼	7.25	..do ...	175	7.95	1,303	1,310	2,082	83.35	23,500
	October 17, 1878, and June 11, 1879	2		35	22¼	7.25	..do ...	178	7.95	1,306	1,313	2,127	85.17	24,500
	May 23 and 27, and June 11, 1879	4		35	22¼	7.25	..do ...	179	7.95	1,342	1,349	2,258	90.40	25,000
	October 25, 1878, and May 9, 13, and 21, and June 11, 1879	8		35	22¼	7.25	..do ...	180	7.95	1,339	1,347	2,263	90.6	26,750
	October 17 and 25, 1878, and May 8, 9, and 27, and June 11, 1879	11		35	22¼	7.25	..do ...	181	7,95	1,347	1,355	2,303	92.23	27,122
	August 22 and 23, and November 1, 1878, and May 8, 9, 13, 21, 23, 27 and 28, 1879	29		35	22¼	7.25	..do ...	182	7.95	1,350	1,358	2,321	92.94	26,200
	August 22, and December 5, 1878, and May 9, 21, 22, and 28, 1879	8		35	22¼	7.25	..do ...	183	7.95	1,342	1,350	2,312	92.56	26,188
	August 8 and 9, and October 18, 1878, and May 21, 1879	9		35	22¼	7.25	..do ...	184	7.95	1,319	1,326	2,242	89.79	26,777
	August 2, 8, and 9, 1878	7		35	22¼	7.25	..do ...	185	7.95	1,313	1,320	2,234	89.45	25,428
	August 8 and 17, 1878	7		35	22¼	7.25	..do ...	186	7.95	1,336	1,342	2,322	92.975	27,643
	June 6 and 10, 1879	1	DuPont's hexagonal G. H. Den'ty, 1.785; gran. 67.	35	22¼	7.25	..do ...	177	7.95	....	.....	....	....	28,500
		2		35	22¼	7.25	..do ...	178	7.95	1,321	1,328	2,176	87.13	28,000
		3		35	22¼	7.25	..do ...	179	7.95	....	.....	....	....	.....
		7		36	22¼	7.25	..do ...	180	7.95	1,312	1,319	2,171	86.92	24,800
		5		35	22¼	7.25	..do ...	181	7.95	....	.....	....	....	.....
		14		35	22¼	7.25	..do ...	182	7.95	1,293	1,300	2,132	85.37	25,833
		5		35	22¼	7.25	..do ...	183	7.95	1,264	1,271	2,049	82.05	24,000

TABLE No. 1.—*Record of firings for endurance with an experimental* 8″ *breech-loading rifle, from August* 1, 1878, *to August* 27, 1879, *&c.*—Continued.

Description of gun.	Date.	Number of shots.	Charge. Kind of powder.	Charge. Cartridge. Weight.	Charge. Cartridge. Height.	Charge. Cartridge. Diameter.	Projectile. Kind.	Projectile. Weight.	Projectile. Diameter.	Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulangé's chonograph.	Velocities at the muzzle.	Energy of projectile. Total at the muzzle. $\frac{WV^2}{2g2240}$	Energy of projectile. Per inch of shot's circumference. $\frac{WV^2}{4g\pi R2240}$	Gas pressure per square inch of bore, as taken with Rodman's internal pressure gauge.
				Lbs	*In.*	*In.*		*Lbs*	*In.*	*Feet.*	*Feet.*	*Ft. tons.*	*Foot-tons.*	*Pounds.*
An 8-inch breech-loading rifle converted from a 10-inch Rodman smooth-bore by lining with a steel-jacketed coiled wrought-iron tube, inserted from the breech; jacket of the tube being prolonged to the rear and adapted for reception of the round wedge fermeture. Caliber, 8 inches. Total length of gun, 147.25 inches. Length of rifled portion of bore, including bevel, 101.25 inches. Length of chamber, 22 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15 each. Twist uniform, one turn in forty feet. Weight of gun, 17,075 pounds.	July 9, 1879	1	Du Pont's hexagonal E. V. J. Density, 1.750; granulation, 72.	*25	16¼	7.25	..do	180	7.95	....	....	....	....	....
	June 11, 1879	1		*30	19¼	7.25	..do	180	7.95	1,272	1,279	2,041	81.73	27,000
	June 18 and 21, July 9, and August 15, 1879	5		35	22¼	7.25	..do	175	7.95	1,423	1,432	2,488	99.6	34,750
	June 11 and 21, 1879	5		35	22¼	7.25	..do	177	7.95	1,411	1,420	2,474	99.06	36,500
	June 11, 18, and 21, and July 9, 1879	12		35	22¼	7.25	..do	178	7.95	1,423	1,432	2,530	101.31	37,250
	June 11, 18, and 21, July 9 and 11, and August 13, 15, and 27, 1879	24		35	22¼	7.25	..do	180	7.95	1,397	1,405	2,463	98.62	36,500
	June 18, and August 13, 14, and 15, 1879	14		35	22¼	7.25	..do	181	7.95	1,393	1,401	2,463	98.62	38,700
	June 18, and July 11, 1879	3		35	22¼	7.25	..do	182	7.95	1,405	1,413	2,519	100.86	40,166
	June 18, and August 13, 1879	2		35	22¼	7.25	..do	183	7.95	1,394	1,402	2,474	99.84	38,500
	August 13, 1879	1		35	22¼	7.25	..do	184	7.95	....	....	....	....	34,500
	July 9, 1879	1		35	22¼	7.25	..do	185	7.95	1,388	1,396	2,499	100.07	35,500
		195												

* These charges were exceptional, being used in test of gas-check.

REMARKS.—During the firings, gas-checks of steel (Broadwell), of copper, and of copper and steel were employed. 4.58 feet was the limit of recoil for the gun. Distance of first wire target from the gun, 60 feet; distance between first and second targets, 100 feet. Mean weight of projectile, using battering charges (35 pounds), 181.06 pounds. Mean velocity at muzzle, using battering charges (35 pounds), 1,363.47 feet. Mean maximum pressure, using battering charges (35 pounds), 30,302 pounds. Mean energy at muzzle, using battering charges (35 pounds), 2,333.58 foot-tons.

TABLE No. 2.—*Record of firings with an experimental 8″ breech-loading rifle, from August 1 to August 2, 1878, inclusive, at Sandy Hook, New York Harbor.*

Description of gun.	Date.	Number of shots.	Charge.				Projectile.				Velocities at 110 feet from muzzle of gun.	Maximum pressures per square inch at surface of bore.	Remarks.
			Kind of powder.	Cartridge.			Kind.	Weight.	Length.	Diameter.			
				Weight.	Height.	Diameter.							
				Lbs.	*In.*	*In.*		*Lbs.*	*In.*	*In.*	*Feet.*	*Lbs.*	
An 8-inch breech-loading rifle, converted from a 10-inch Rodman smooth-bore by lining with a steel jacketed, coiled, wrought-iron tube, inserted from the breech, jacket of the tube being prolonged to the rear and adapted for reception of the round-wedge fermeture. Caliber, 8 inches. Total length of gun, 147.25 inches. Length of rifled portion of bore, including bevel, 101.25 inches. Length of chamber, 22 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15 each. Twist uniform, one turn in forty feet. Weight of gun, 17,075 pounds.	Aug. 1, 1878	1	Du Pont's hexagonal F. P. B. Density, 1.785; gran., 67.	15	10	7.25	Butler	185	......	7.95	....	8,000	All these shots were fired into the butt, and were preliminary to the test of the gun for endurance.
	Aug. 1, 1878	2		20	13¼	7.25	...do...	185	......	7.95	....	20,000	
	Aug. 1, 1878	3		20	13¼	7.25	...do...	185	......	7.95	....	14,500	
	Aug. 1, 1878	4		25	16¼	7.25	...do...	184	......	7.95	....	25,000	
	Aug. 1, 1878	5		25	16¼	7.25	...do...	185	......	7.95	....	21,500	
	Aug. 2, 1878	6		30	19¼	7.25	...do...	183	......	7.95	....	21,500	
	Aug. 2, 1878	7		30	19¼	7.25	...do...	185	......	7.95	1,220	22,000	

APPENDIX I[11].

PROGRESS REPORT ON 11-INCH MUZZLE-LOADING RIFLE, CONVERTED FROM A 15-INCH SMOOTH-BORE GUN.

A full description of the gun will be found in the report of the Constructor of Ordnance. It is mounted on the ordinary 15-inch service-carriage, provided with pneumatic buffers for checking recoil.

By the record it will be seen the gun has been fired 33 rounds with charges varying from 70 to 85 pounds; the projectiles varying in weight from 503 to 552 pounds. Various powders have been used in the tests in the endeavor to find one best suited for the trial of the gun. The sample I. H. (see record), the last tried, has given fair results—with 85 pounds of powder and a shell weighing 552 pounds—the recorded velocity being 1,290 feet, with a corresponding pressure of 30,000 pounds. Experiments will be continued when the supply for the tests recently ordered from the Messrs. Du Pont & Co. shall have been received.

The gun remains in a sound and serviceable condition.

AVERAGES.

Record of firing with 11" muzzle-loading converted rifle at Sandy Hook, New York Harbor, from August 1 to October 7, 1879, inclusive.

Description of gun.	Date.	Number of rounds.	Powder. Kind.	Powder. Weight.	Projectile. Kind.	Projectile. Weight.	Pressure, pounds per square inch of bore.	Velocity recorded at 110 feet from muzzle.	Recoil.	Counter-recoil.
A rifle converted from a 15-inch Rodman smooth-bore by lining with a jacketed wrought-iron coiled tube inserted from the rear. Caliber, 11 inches. Total length of gun, 190 inches. Length of bore, 161.5 inches. Length of rifling, 141.5 inches. Diameter of bore, including grooves, 11.18 inches. Number of grooves and lands, 19 each. Twist uniform, one turn in 60 feet. Weight of gun, 54,730 pounds.	1879.			*Lbs.*		*Lbs.*		*Lbs.*	*Feet.*	*Feet.*
	August 1	2	Du Pont's hexagonal G. H.; den., 1.785; gran., 67.	70	Butler	503	34,250	1,258	7.18	3.44
	August 1	2		75	....do	504	42,000	1,300	7.42	4.00
	August 6	1	Du Pont's hexagonal F. P. C.; den., 1.785; gran., 67.	70	....do	503	39,000	1,305	7.75	1.50
	August 8, 12, and 13	4	Du Pont's hexagonal H. R.; den., 1.78; gran., 50.	70	Butler shell	505	35,500	1,293	7.42	3.83
	Aug. 12 and Sept. 10	2	Du Pont's hexagonal H. S.; den., 1.8; gran., 50.	70	....do	504½	35,250	1,302	7.58	3.79
	September 10	2		75	....do	505	34,000	1,318	7.85	2.27
	August 14	2	Du Pont's hexagonal F. P. B.; den., 1.785; gran., 67.	70	....do	506	34,500	1,278	7.40	3.12
	August 14	2	Du Pont's square G. S.; den., 1.775; gran., 11.	70	....do	504	24,750	1,212	6.83	1.66
	August 15	1		75	....do	506	25,500	1,216	7.13	1.96
	August 15	1		80	....do	506	30,000	1,263	7.42	2.33
	August 15	1		85	....do	506	24,500	1,235	7.50	2.33
	August 20 and 22	3	Du Pont's square G. T.; den., 1.76; gran., 11.	70	....do	505	31,500	1,245	7.33	3.14
	September 10	1		75	....do	505	33,000	1,316	7.75	3.00
	August 15	2	*G. T. and H. R., 42 and 28 pounds mixed.	70	....do	506	34,275	1,266	7.22	1.62
	August 15	1	Du Pont's square G. W.; den., 1.715; gran., 11.	70	... do	506	33,500	1,256	7.08	1.71
	October 7	1	Du Pont's hexagonal I. H.; den., 1.80; gran., 40.	70	....do	506	23,500	1,237	7.33	5.08
	October 7	1		70	....do	550	22,500	1,194	7.83	3.83
	October 7	1		75	....do	550	25,000	1,232	7.75	2.25
	October 7	1		80	....do	503	27,000	1,318	7.83	1.67
	October 7	1		80	....do	552	27,000	1,253	8.17	.67
	October 7	1		85	....do	552	30,000	1,290	8.33	.42
	October 7	1	Du Pont's hexagonal I. G.; den., 1.77; gran., 40.	70	....do	504	37,500	1,320	7.75	4.17
		33								

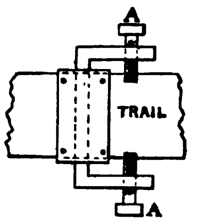
*One round—H. R. and G. T. powder thoroughly mixed in the following manner: 6 pounds of G. T. and 4 pounds of H. R. weighed separately, then thoroughly mixed and poured into the cartridge-bag, and this repeated seven times. The other round, 42 pounds of G. T. powder was first put in cartridge-bag and 28 pounds of H. R. placed on top.

APPENDIX I[12].

REPORTS ON A GATLING GUN, CALIBER 45-INCH (ENGLISH MODÉL), HAVING A NEW POINTING APPARATUS.

(Fifteen plates.)

SIR: In compliance with the instructions of the Acting Chief of Ordnance, of September 1, 1879, in third indorsement on Capt. J. E. Greer's report of April 2, 1879 (1176 of 1879), the Board has the honor to report that the tests ordered were made at Sandy Hook on the 25th, 26th, and 27th ultimo. The fixtures differ from those described in the report of the board of April 4, 1879, in the following particulars only: The taper key or wedge, which fitted under the lever and between it and the swiveled steel box through which it passed, has been omitted, it being replaced by a simple clamp-screw. This clamp is now on the left of the swiveled box, and the clamp for the turn-table, formerly on the right, has been transferred to the left side to be within reach of the left hand, the right hand remaining always at the firing crank. The screw-clamp was substituted for the wedge, as it was feared that the latter might become rusted and give trouble by sticking in its seat. A simple device for limiting the oscillation, as shown in this rough sketch, has been attached to the stock, and could be used or not, as circumstances warranted. When in use it is turned up so as to limit the play of the lever, the amplitude of the oscillation being regulated by the screws A A (see Plates XI, XII).



With this arrangement six targets were fired, four of them being at 200 yards distance and the remaining at 500 yards (see target plottings appended and marked 1, 2, 3, 4, 5, and 6, Plates I, II, III, IV, V, and VI). In all 10 series of 500 rounds each were fired at targets 11 by 52 feet, made of 1-inch spruce boards. Of the 500 rounds fired at the first and second targets at 200 yards, all were direct hits; at the 500-yard targets (Nos. 3 and 4), the hits were respectively 453 and 489.

Up to this time 5 men had been employed in the service of the piece, the average time occupied in firing 500 rounds being 1′ 29¾″. The men were not, however, required to fire as rapidly as possible during these trials.

The fifth and sixth targets, at 200 yards, were fired by three men, one turning the crank, one feeding and handling cases, and one attending to the oscillator or lever, the clamps being unscrewed and the gun free to move both vertically and horizontally. An examination of these targets—on the first of which there were but 75 and on the second but 148 hits—shows how difficult it is to control the dispersion, the hand alone controlling the lever, and that it is necessary to clamp the lever to prevent too great oscillation.

The seventh, eighth, ninth, and tenth targets (Plates VII, VIII, IX, and X), at 200 yards, show good results, the hits being respectively 497, 467, 473, and 488; in these targets the straight lever was replaced by one forked at the end to enable the man directing the gun, by placing his body between the forks, to better control the dispersion. Whilst

firing the seventh target the device attached to the stock for limiting the oscillation was used, the clamp on oscillating lever being unscrewed; but whilst firing the eighth, ninth, and tenth the oscillation was controlled by the lever alone, the clamp-screw being fastened and the gun having only that much of vertical oscillation which would be due to the play of the gun in firing. The average time occupied by three men in firing the fifth and sixth targets was 50¾"; two men fired the seventh target in 51¼"; and the average time occupied by one man alone, in feeding, firing, and oscillating (eighth, ninth, and tenth targets), was 1' 9⅜".

All the above firings were done with a long 10-barreled, caliber 0".45 Gatling gun (see record of firing appended, marked A, and Plates XI and, XII showing gun, &c.).

GENERAL SUMMARY OF RESULTS.

Targets 11' × 52', of 1-inch spruce boards; 500 rounds at each target; Bridgeport ammunition.

Distance to target.	Number of men employed in service of piece.	Hits.		Time occupied in firing series.	Number of target.	Remarks.
		Direct.	Ricochet.			
Yds.				' "		
200	5	500	......	1 4	1	
200	5	500	......	1 57	2	
300	5	396	57	1 36⅛	3	
300	5	489	......	1 21¼	4	
200	3	75	......	57½	5	Clamp on lever free; vertical dispersion attempted by movement of lever up and down.
200	3	148	......	44½	6	Clamp on lever free; no movement of lever by hand up and down.
200	2	497	.....	51¼	7	Yoke used on end of lever; oscillator stop on trail, used.
200	1	467	......	1 10	8	Yoke used on end of lever; clamp on lever fastened.
200	1	473	......	1 4½	9	Do.
200	1	488	......	1 14½	10	Do.

The Board find the changes in the elevating and traversing fixtures of the Gatling gun, since its last report, in April, 1879, are such as simplify and economize the construction, and add facility to its manoeuvers, and are therefore to be preferred to the fixtures then applied.

The various firings made with this gun, as will be seen from the records of firing appended, show that the gun is handled with great ease and facility, and the fact that one man can work the gun alone, firing 500 rounds in 1⅛ minutes, and making an excellent target, undoubtedly indicates that the improvements have very much simplified and perfected all the operations with this gun to a degree not heretofore attained.

Whether an automatic oscillator can be properly attached, and whether its use is so valuable as to make it an important adjunct, it is impossible for the board at the present time to decide, but as this addition is recommended by Captain Greer, who states in his report that it can be practically applied, and as the settlement of the question whether it should be dispensed with or not has arisen, the Board would recommend that an automatic oscillator be adapted to one of the guns and carriages, with these new features, at the Springfield Armory, as proposed by Captain Greer, and that experiments be made at Sandy Hook to determine this matter; all to be carried out as early as practicable.

Record of firing with Gatling gun, caliber 0''.45, No. 195 (ten long barrels), at Sandy Hook, New York Harbor, from September 25 to September 27, 1879.

No. of fire.	Date.	Ammunition.	Time of firing.	Remarks.
	1879.			
2	Sept. 25	Bridgeport..	....	Sighting shots at 200-yard target.
500	Sept. 25	....do	1' 4''	Target No. 1. Fired at 200-yard target. Total number of hits in target, 500.
500	Sept. 25	....do	1' 57''	Target No. 2. Fired at 200-yard target. Total number of hits in target, 500.
500	Sept. 26	....do	1' 36½''	Target No. 3. Fired at 500-yard target. Total number of hits in target, 453. Direct hits, 396; ricochet hits, 57.
500	Sept. 26	....do	1' 21½''	Target No. 4. Fired at 500-yard target. Total number of hits in target, 489.
500	Sept. 26	....do	57½''	Target No. 5. Fired at 200-yard target. Total number of hits in target, 75. Clamp on oscillating lever free. One man attending to the vertical and horizontal oscillations during the firing. One man firing, and one man feeding and taking out cases.
500	Sept. 26	....do	44½''	Target No. 6. Fired at 200-yard target. Total number of hits in target, 148. Clamp on oscillating lever free. One man attending to the vertical and horizontal oscillations during the firing. One man feeding and taking out cases, and one man firing. Arrangement for limiting oscillation attached to carriage left down during the firing.
500	Sept. 26	....do	51½''	Target No. 7. Fired at 200-yard target. Total number of hits in target, 497. One man firing and oscillating. One man feeding and extracting cases. Oscillation limited by arrangement attached to carriage. Yoke used on end of lever.
500	Sept. 26	....do	1' 10''	Target No. 8. Fired at 200-yard target. Total number of hits in target, 469. One man feeding, firing, and oscillating. Clamp on oscillating lever fastened to prevent vertical oscillation. Yoke used on end of lever.
500	Sept. 27	....do	1' 4½''	Target No. 9. Fired at 200-yard target. Total number of hits in target, 473. One man feeding, firing, and oscillating. Clamp on oscillating lever fastened to prevent vertical oscillation. Yoke used on end of lever.
500	Sept. 27	....do	1' 14½''	Target No. 10. Fired at 200-yard target. Total number of hits in target, 488. One man feeding, firing, and oscillating. Clamp on oscillating lever fastened to prevent vertical oscillation. Yoke used on end of lever.

All targets 11' by 52', made of 1-inch spruce boards. Mechanism of gun worked well during entire firing.

NATIONAL ARMORY,
Springfield, Mass., April 2, 1879.

SIR: In accordance with your instructions to examine the new-model Gatling gun designed for the English service, I have the honor to submit the following report:

In its general features this gun resembles the short 5-barrel gun. It differs from it, however, in the following particulars: The crank is transferred from the rear of the main shaft to the side as in the long guns. This necessitates the addition of a diaphragm which receives and transmits the pressure from the cam directly to the cascabel-plate. The crank-shaft passes in rear of the diaphragm. In order that there may be no loss of speed, as compared with the crank on the main shaft, the pitch of the worm and worm-gear is made the same.

The adjustment is at the rear and the same as in the 5-barrel gun, except that, on account of the change of position of the crank, the adjusting-nut locking-spring is replaced by a slide on the cascabel-plate, which enters the various notches on the inside of the nut. The barrels—six in number—are 24 inches in length, six inches longer than those of the short gun. The gun is bronze-cased throughout. Underneath and at the rear of the casing is pivoted a cubical block of metal, through which, and lengthwise with the gun, is a rectangular slot. A lifter, or elevating-bar, passes through this slot, and is pivoted at its front to the turn-table of either carriage or tripod. This bar is clamped in any position by another bar, slightly wedge-shaped or tapering, lying underneath and passing through the slot mentioned. By slightly withdrawing the wedge, the breech may be elevated or depressed, and again clamped by its reinsertion.

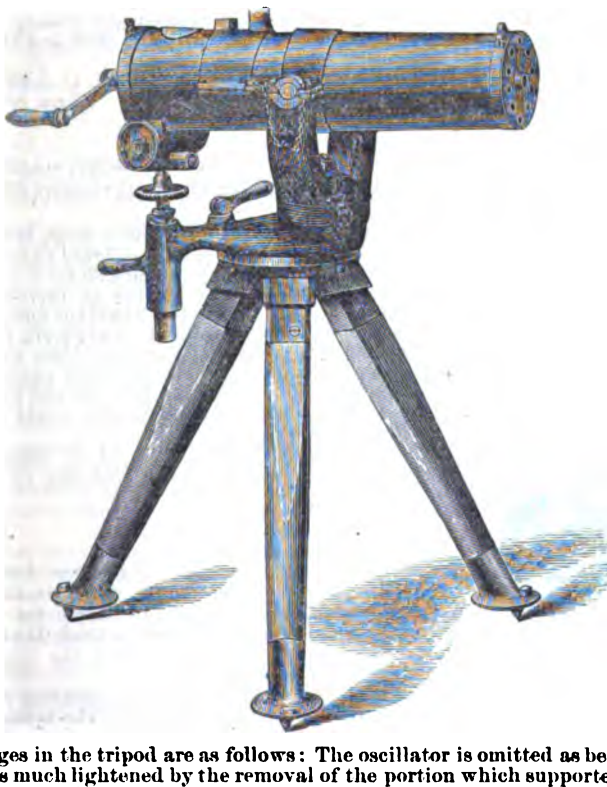
Near the outer end of the elevating-bar a handle is pivoted to it having a groove on it upper surface for the end of the bar when pressed together. A flat spring between the bar and handle rotates the latter downward about the pivot. At the lower front

end of the handle is a sort of hook which receives a projecting pin on the rear of the wedge.

The pivot about which the handle turns being at its upper front end, upward motion of the rear withdraws the wedge. In order then to change the elevation it is only necessary to press the end of the bar and handle together, and then raise or lower at pleasure. This may be easily and readily done with one hand. On relaxing the pressure of the hand the spring throws the handle down and returns the wedge.

The elevating-bar may also be clamped, if necessary, for long-continued firing by a screw-binder through the projection on the under side of the casing. The advantages of this method of changing the elevation are very great. The elevating-screw, with its limited movement of breech and slow motion, is dispensed with; the vertical angle through which the gun may be moved is vastly increased—15° elevation and 30° depression now being given—and the time reduced to a minimum. With the elevating-screw the short and long guns cannot be mounted on the same carriage without greatly weakening the stock by the insertion of two elevating-screw boxes near together. By the means last adopted either gun may be mounted on any carriage or tripod in service. The oscillator is also dispensed with, the gun being turned to the right or left by the handle of the elevating-bar. The turn-table may be clamped to its bed by a screw-binder if no horizontal motion is desired.

SYSTEM NOW IN USE.



The changes in the tripod are as follows: The oscillator is omitted as before, and the turn-table is much lightened by the removal of the portion which supported the elevating-screw and its lifter. The turn-table binder has been altered from that of an eccentric to a screw. It has been found that by continued firing the legs of the tripod had a tendency to work together, endangering the stability of the piece, sometimes even to the extent of a complete overthrow. To correct this, jointed braces have been placed between the legs. These fold up with the legs during transportation. So far as facility of directing the piece from the tripod is concerned, the new method is not greatly superior to that in use, because the piece may now be turned through a horizontal arc of 360°, and by means of the elevating-screw lifter the elevation may be quickly given; but as the new method enables any gun to be fired from either carriage or tripod it is particularly desirable. The reduction in weight of the tripod is also a valuable feature.

The great advantage, however, is derived when the piece is mounted on the carriage where the elevation is given by the screw alone, and the horizontal motion is exceedingly limited without movement of the trail. In view, then, of the great apparent superiority of the new system over that in service, I would respectfully suggest that a gun and carriage of the latest model be purchased for experiment and trial, or that one of those now on hand be altered for the purpose mentioned.

Plates XIII, XIV, and XV, illustrative of the system, are submitted herewith.

[First indorsement.]

NATIONAL ARMORY, *April* 2, 1879.

Respectfully forwarded to the Chief of Ordnance, approving the recommendation that a specimen of the new pointing apparatus be procured from the Gatling Gun Company, for trial with one of the guns belonging to the Ordnance Department.

J. G. BENTON,
Lieutenant-Colonel, Commanding.

[Second indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 4, 1879.

Respectfully returned to the commanding officer of National Armory, authorizing the purchase of a specimen of the new pointing apparatus for trial and report. * *

By order of the Chief or Ordnance.

S. C. LYFORD,
Major of Ordnance.

[Third indorsement.]

NATIONAL ARMORY, *August* 29, 1879.

Respectfully returned to the Chief of Ordnance, together with Captain Greer's report, dated August 26, 1879.

I am of opinion that the new apparatus for pointing Gatling guns, herein referred to, is equal to the old one for steadiness, and much superior in rapid execution. In it Dr. Gatling has omitted the old automatic oscillator and substituted for it an oscillation by hand. As this is an important point, and one that cannot be properly tested at this place for the want of a proper firing ground, I recommend that the entire subject be transferred to the Ordnance Board for trial and determination at Sandy Hook.

Many improvements have been introduced in Gatling guns since their first introduction into the service, making a variety of models of both guns and carriages now in the hands of the troops. Some effort should be made to reconcile the differences by applying the improvements to all, so far as practicable, and this would seem to be a proper subject for the consideration of the Board.

J. G. BENTON,
Colonel of Ordnance, Commanding.

NATIONAL ARMORY,
Springfield, Mass., August 26, 1879.

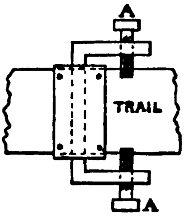
SIR: In my report of April 2 attention was called to a new device for elevating or depressing and pointing of Gatling guns, and a recommendation made that one be purchased for trial. That recommendation having been approved, the apparatus was ordered from the Gatling Gun Company, of Hartford, Conn.

On its receipt there was found accompanying it a second one, differing from the one described in the report mentioned in the following particulars: The taper or friction-bar underneath the elevating-bar is omitted, and a brass yoke or fork of a size sufficient to admit the average man between the branches is pinned to the outer end of the elevating-bar. A leather strap at the end of this bar passes over the shoulders of the one turning the crank, and enables him to hold the bar at any desired height. The oscillation is supposed to be given by his pressing alternately against the branches of the fork, the turn-table being unclamped. The screw-binder is transferred to the left side of the bar to enable one man to clamp the bar without stopping the firing. The friction-bar was omitted, through fear that it might become rusted in its seat and give trouble, especially as the lever power at the handle was very slight for withdrawing it. This was probably advisable, though by slight modifications this power might be considerably increased. The first device required the oscillation to be given by the left hand at the end of the elevating-bar, the right being at the crank. The elevation once given remained fixed until purposely altered. In the second the elevation

could be altered by the raising or lowering of the shoulders over which the strap passed. Trial with the first one confirmed the advisability of dispensing with the friction-bar, and with the second demonstrated the uselessness of the yoke and the strap, it being simply impossible to oscillate the gun while turning. The crank being on the right side, the power applied to turn it carried the muzzle of the gun to the right. In addition, the weight on the shoulders was oppressive, and in giving great depression to the muzzle the yoke came in contact with the crank-handle.

The difficulties in working were somewhat increased by the sticking of the Frankford service cartridges. These were manufactured in January of this year, and were known to stick even in the Springfield rifle. Other cartridges caused the gun to work more satisfactorily, but the trials showed conclusively that the oscillation must be automatic or not at all. The second of the two devices with yoke and strap omitted, but with the outer end of the elevating-bar altered so as to form a handle, is believed to be the most desirable. This gives elevation or depression alone, but by unclamping the turn-table the gun may be quickly pointed and again clamped.

In a recent conversation with Dr. Gatling, he gave it as his opinion that the oscillation should be given by the elevating-bar alone, no better means having been suggested, but admitted that it would require the entire service of an additional man. Even then it is impracticable, owing to the lack of unity between the power applied at the end of the bar and the crank-handle. He also proposed to limit the oscillation by a device similar to that shown on the margin, attached to the trail, and which may be readily rotated so as to receive a lug on the turn-table between the screws A, A, the amplitude of the oscillation being regulated by the space between the screws, or be turned down on the trail, allowing the piece to be pointed in any direction. This, it will be seen, is a partial return to the automatic oscillator.



As it was thought that the present automatic oscillator should not be abandoned until something better of the same nature had been devised, I suggested its combination with the new method of giving the elevation. This was done by the addition to the sliding-block on the elevating-bar of a swivel, the outer end of which terminated in a cylindrical piece just sufficient to fill that portion of the oscillator which ordinarily receives the knob of the elevating-screw, and by the omission of the piece now swiveled to the block and connected rigidly with the gun. A pin through the oscillator and cylindrical part of the swivel prevented the latter from sliding out of its seat. By this means the automatic oscillation was retained with all the desirable features of the new elevating apparatus, and the whole was found to work fairly. In making a new oscillator the swivel part should be cast solid with it for simplicity and cheapness.

The oscillating motion necessitates the trunnion-swivel being cast separate from the turn-table, and, consequently, admits the use of those now on the carriages.

One objection to the change made at Hartford is that it requires calling in the guns in order that the piece which replaces the oscillator may be permanently fastened to them. They could not then be used on the present carriages.

As modified here, a part of the oscillator not in contact with the gun was slightly changed, but as the oscillator is classed as a part of, and is issued with the carriage, the whole would be together, and the gun could be mounted on either carriage, old or new.

The present tripod system, though heavier and more expensive than the one proposed, gives elevation, depression, and oscillation without moving the legs of the tripod.

If the same system were adapted to the carriage, the piece could be quickly pointed without moving the trail, and the elevation could be given as rapidly as with the new device.

I would respectfully suggest that Dr. Gatling be invited to visit this armory and witness the working of the parts as modified here.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A.

The COMMANDING OFFICER,
National Armory.

[Indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, September 1, 1879.

Respectfully referred to the Ordnance Board U. S. A., for trial and report, and with directions to communicate with the Gatling Gun Company as to time.

S. C. LYFORD,
Acting Chief of Ordnance.

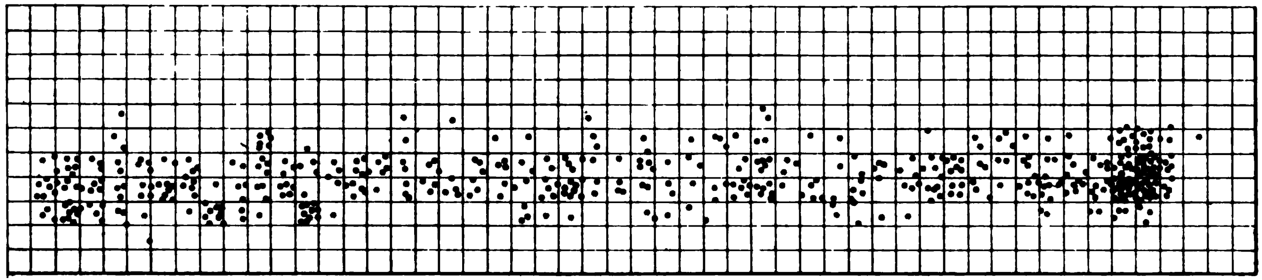
TARGET NO. I.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

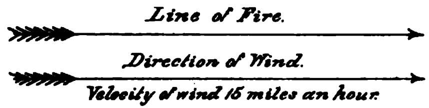
At Sandy Hook, N. J., Sept. 25th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 500.*



Target 11 x 52 Feet. Made of Spruce Boards. (1 inch.)



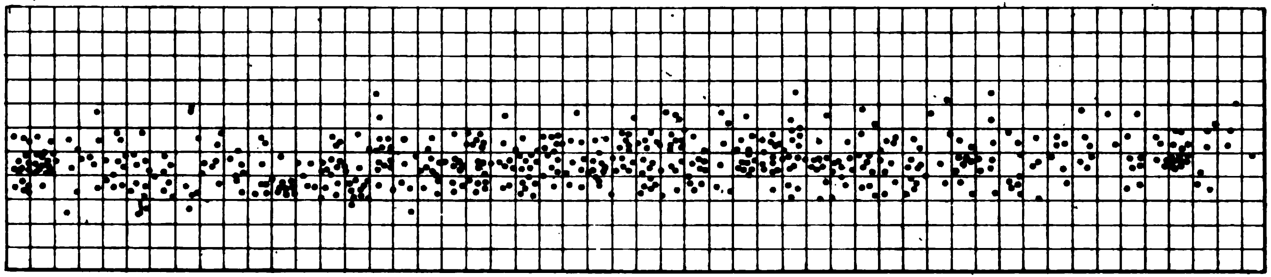
TARGET NO. 2.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

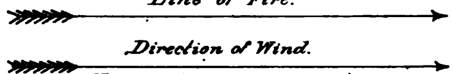
At Sandy Hook, N. J., Sept. 25th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 500.*



Target 11 x 52 Feet. Made of Spruce Boards. (1 inch.)

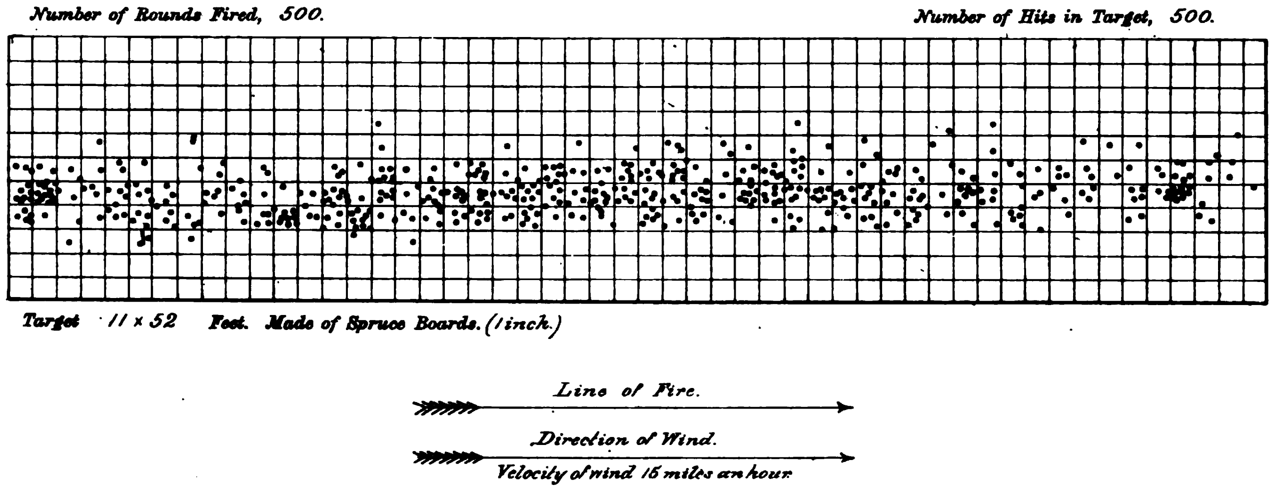


TARGET NO. 2.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

At Sandy Hook, N. J., Sept. 25th, 1879.

Target 200 Yards from Gun.



TARGET NO. 3.

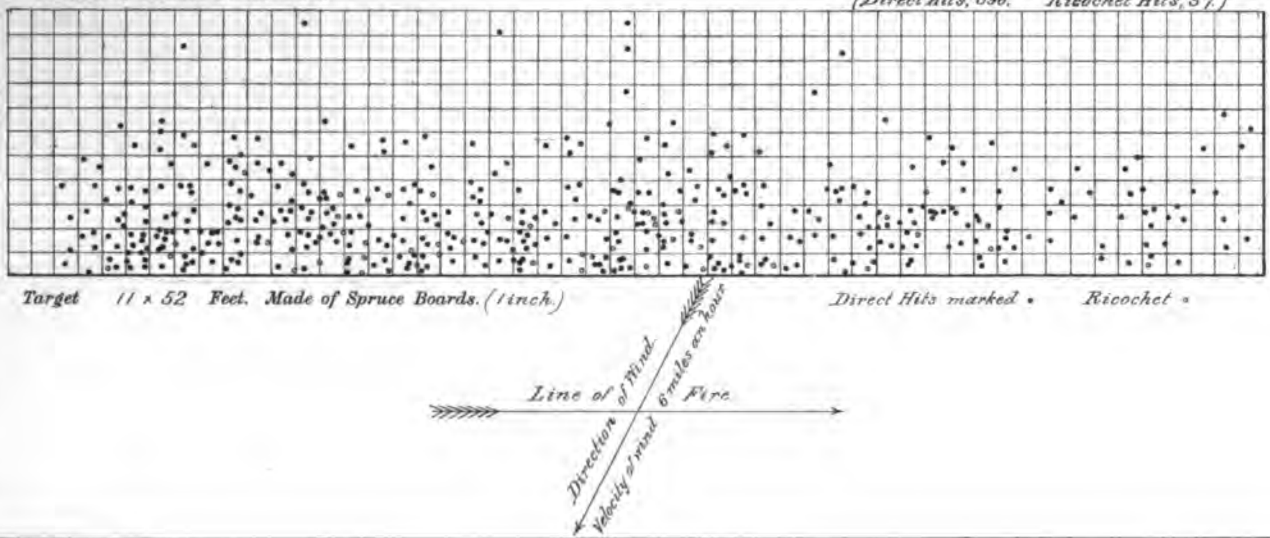
TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

At Sandy Hook, N. J., Sept. 26th, 1879.

Target 500 Yards from Gun.

Number of Rounds Fired, 500.

Number of Hits in Target, 453.
(Direct Hits, 396. Ricochet Hits, 57.)



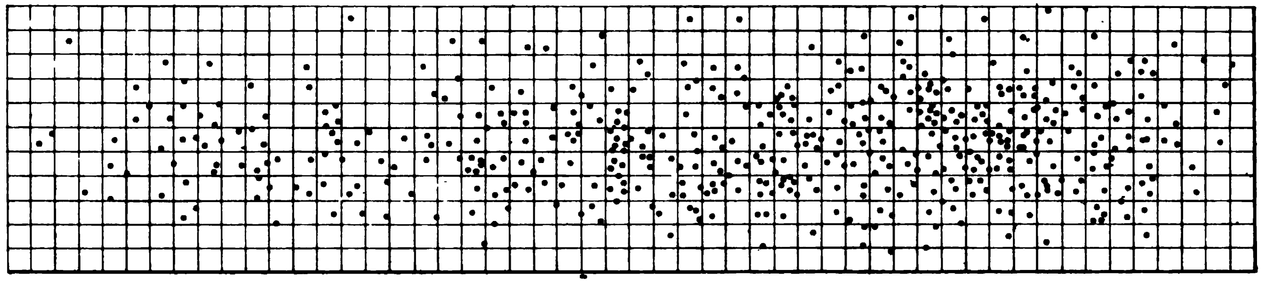
TARGET NO. 4.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

At Sandy Hook, N. J., Sept. 26th, 1879.

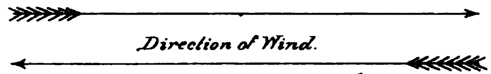
Target 500 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 489.*



Target 11 x 52 Feet. Made of Spruce Boards. (1 inch.)

Line of Fire.



Direction of Wind.

Velocity of wind 6 miles an hour.

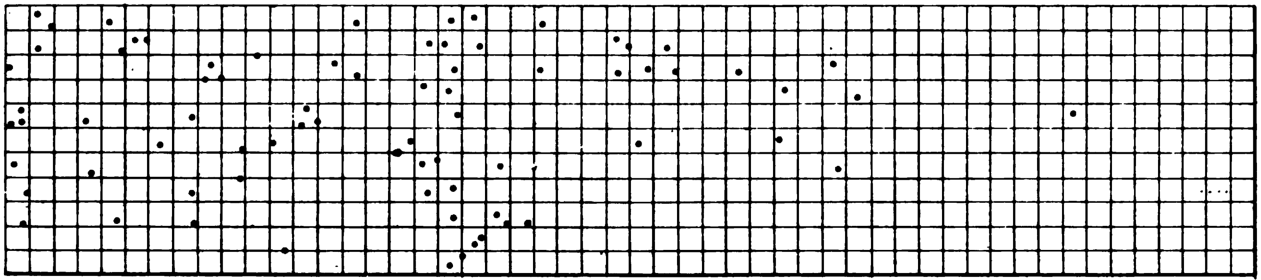
TARGET NO. 5.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

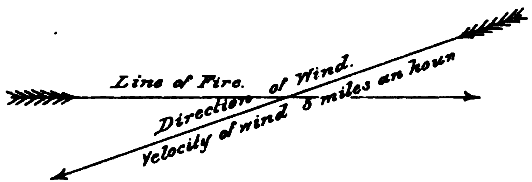
At Sandy Hook, N. J., Sept. 26th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 75.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.)



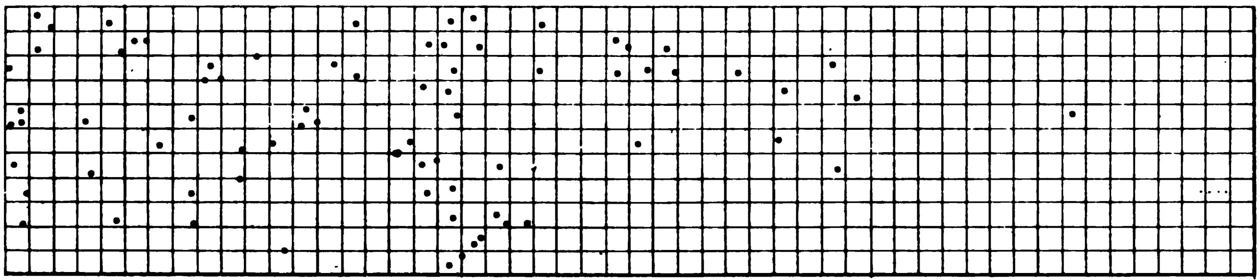
TARGET NO. 5.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

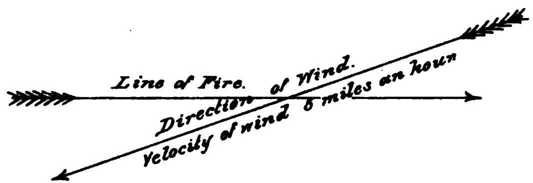
At Sandy Hook, N. J., Sept. 26th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 75.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.)



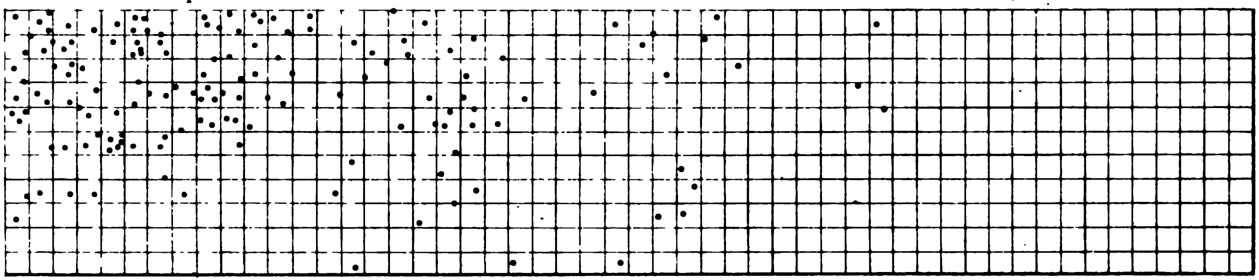
TARGET NO. 6.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

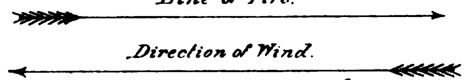
At Sandy Hook, N. J., Sept. 26th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 148.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.)



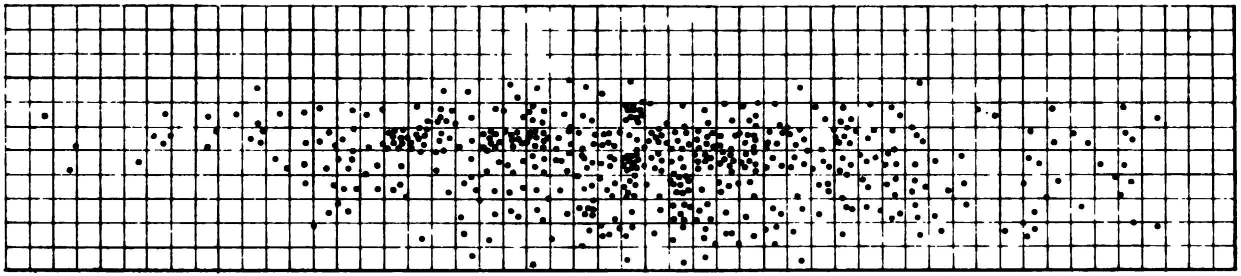
TARGET NO. 7.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

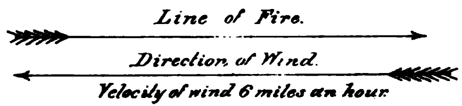
At Sandy Hook, N. J., Sept. 26th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 497.*



Target 11 x 52 Feet. Made of Spruce Boards. (1 inch.)



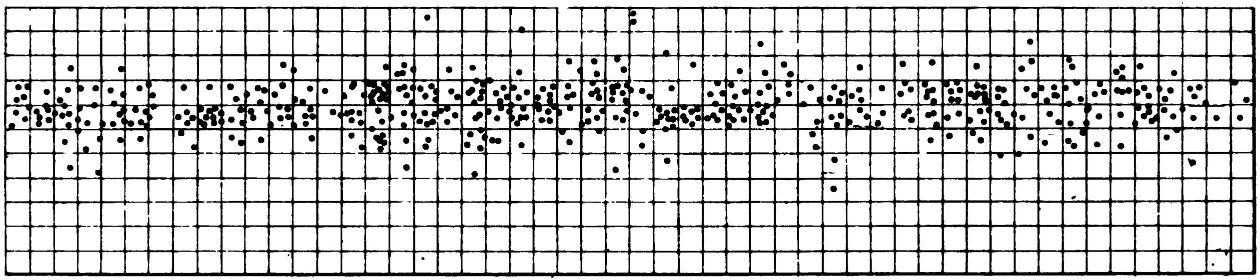
TARGET NO. 8.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

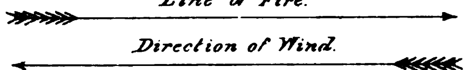
At Sandy Hook, N. J., Sept. 26th, 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 469.*



Target 11 x 52 Feet. Made of Spruce Boards. (1 inch.)



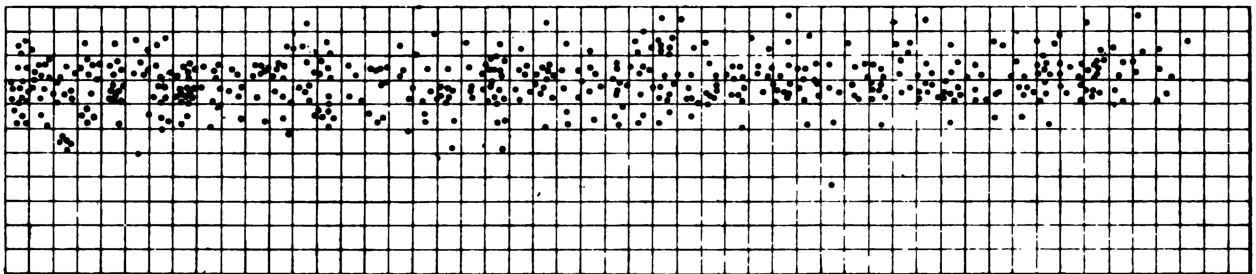
TARGET NO. 9.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

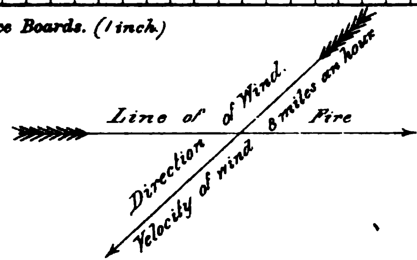
At Sandy Hook, N. J., Sept. 27th. 1879.

Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 473.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.)



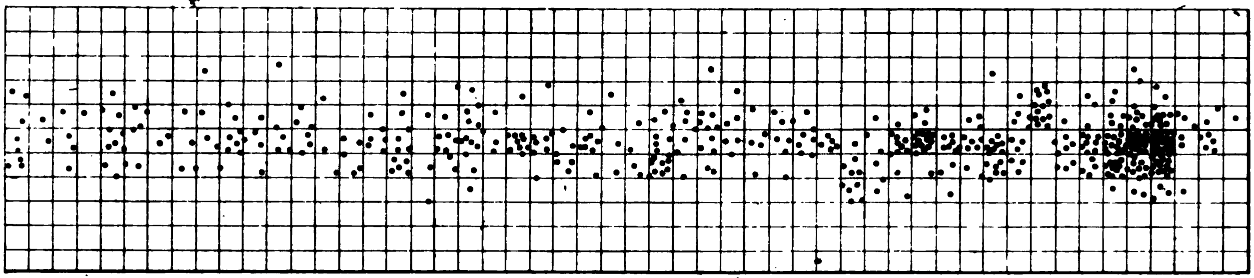
TARGET NO. 10.

TARGET RECORD. 10 BARREL (LONG) GATLING GUN, CAL. .45 INCH.

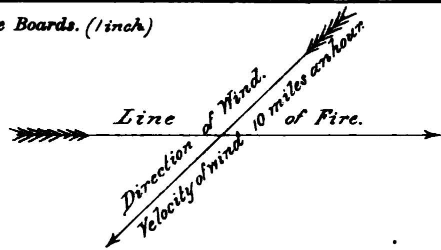
At Sandy Hook, N. J., Sept. 27th, 1879.

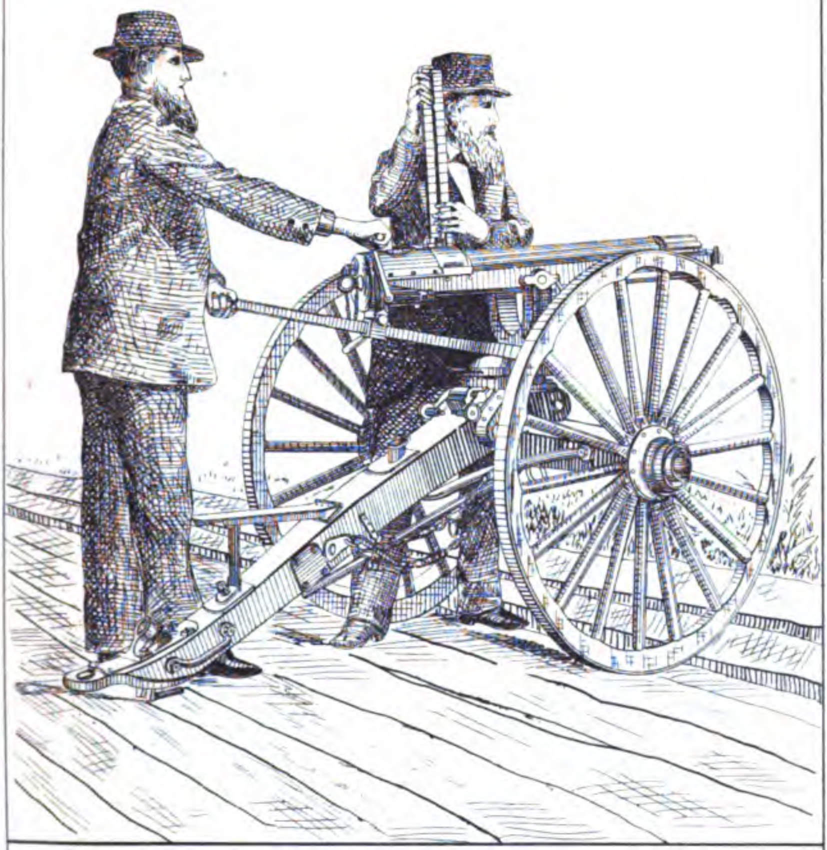
Target 200 Yards from Gun.

Number of Rounds Fired, 500. *Number of Hits in Target, 488.*



Target 11 x 52 Feet. Made of Spruce Boards. (1 inch)

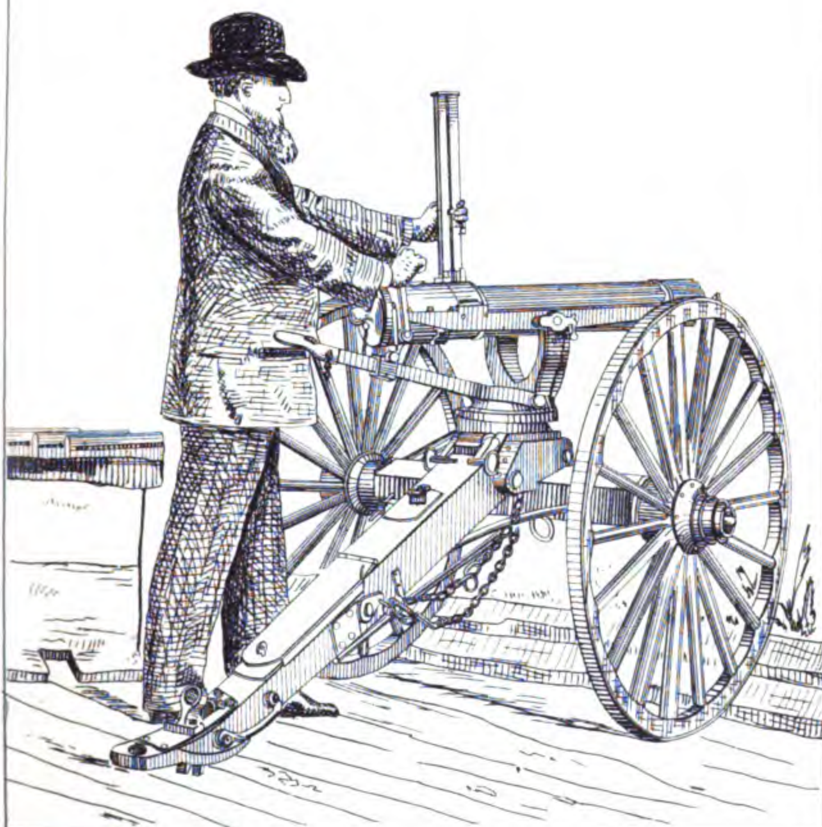




LONG 10-BARREL GATLING GUN, CAL. 0".45.

Showing Improved Fixtures for Elevating and Oscillating Gun, straight lever; also, fixture for limiting oscillation.

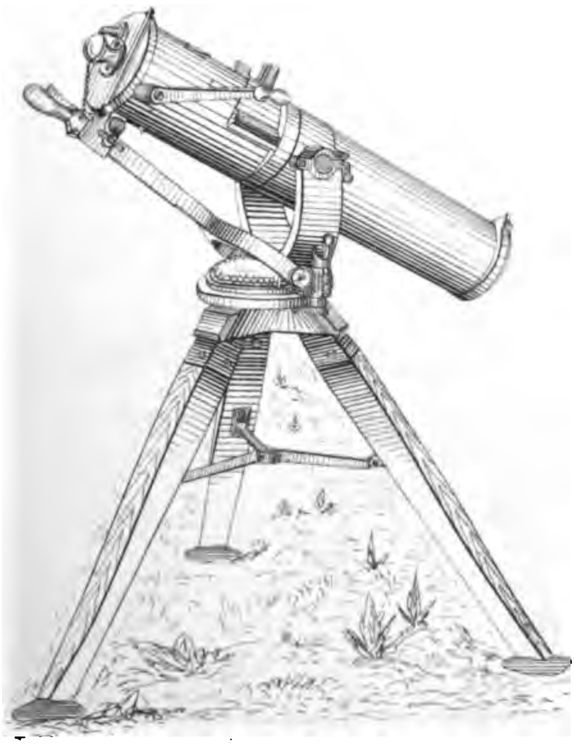
(DOWN—Not in use as shown.)



LONG 10-BARREL GATLING GUN, CAL. 0".45.

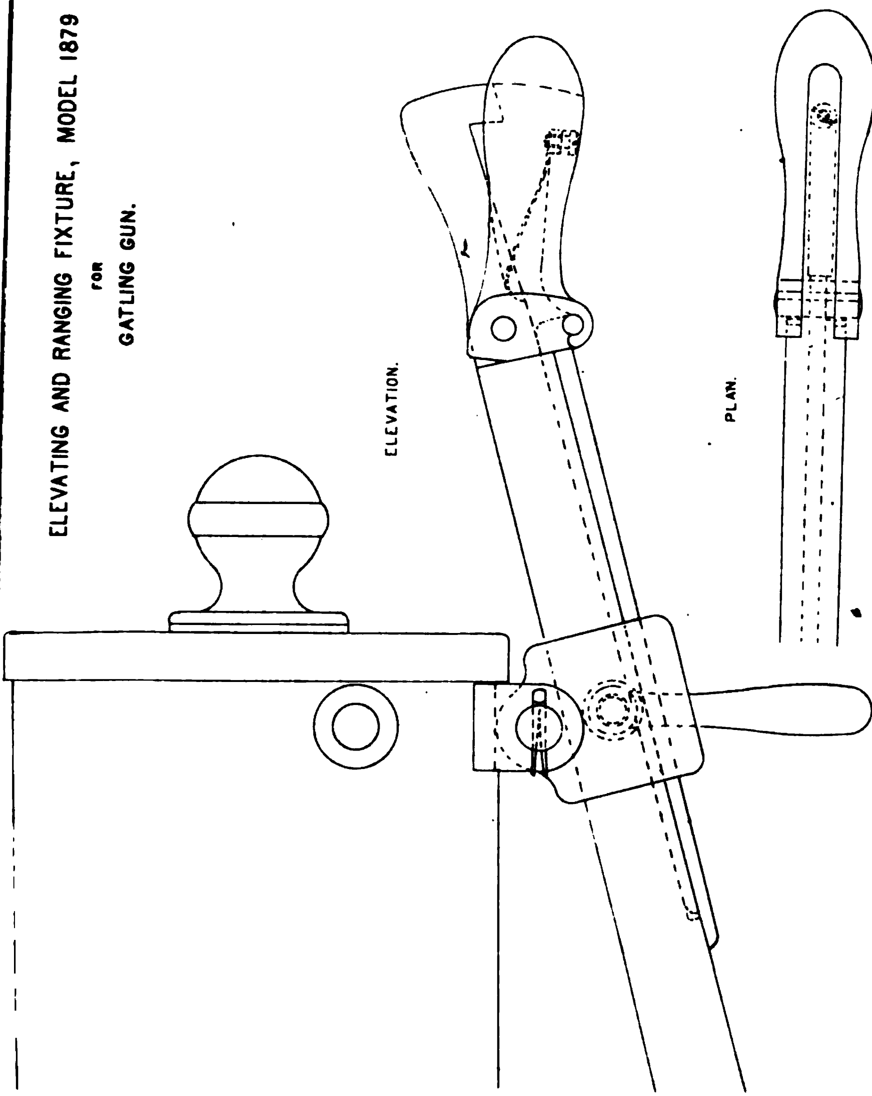
Showing Fixtures for Elevating and Oscillating Gun, having fork attached to lever; also, fixture attached to stock for limiting oscillation.

(DOWN—Not in use as shown.)



NEW MODEL GATLING GUN.
Designed for the English Service.

ELEVATING AND RANGING FIXTURE, MODEL 1879
FOR
GATLING GUN.



APPENDIX I[13].

REPORT ON MULTIBALL CARTRIDGES FOR GATLING GUN.

(Thirteen plates.)

HARTFORD, CONN., *September* 14, 1878.

SIR: We have the honor to request a trial of Wright's multiball cartridges in the Gatling gun, the accounts we receive indicating them well adapted for use in a Gatling gun on special occasions.

We have the honor to be, with great respect, your obedient servants,

GATLING GUN COMPANY,
By EDGAR T. WELLES,
Treasurer.

Gen. S. V. BENÉT,
Chief of Ordnance, U. S. A., Washington, D. C.

[First indorsement.]

ORDNANCE OFFICE, *September* 16, 1878.

Respectfully referred to the Ordnance Board. Ten thousand of these cartridges have been ordered to be made at the Frankford Arsenal and issued to Lieutenant Starring. When received please make such trials with them as will test their suitability for use in this gun, and communicate with the writer.

S. C. LYFORD,
Acting Chief of Ordnance.

[Second indorsement.]

THE ORDNANCE BOARD,
New York City, October 15, 1878.

Respectfully returned to the Chief of Ordnance, with record of firings made at Sandy Hook, October 3 and 4, with the multiball cartridges, and target records of same. (See Plates I, II, III, IV, and V.) Duplicates have been furnished Mr. Welles.

S. CRISPIN,
Bvt. Col. U. S. A., Lt. Col. of Ord., President of the Board.

Record of firing with 10-barrel Gatling gun, caliber 0″.45, at Sandy Hook, New Yokr Harbor, from October 3 to October 4, 1878.

No. of rounds.	Date.	Ammunition.	Remarks.
2,000	Oct. 3, 1878	Wright's multiball cartridges; charge, 45 grains; three round bullets in each cartridge; weight, 133 grains each.	Target No. 1: Fired at 100-yard target (600 fired at center of target, 600 fired eight feet to left, 400 fired thirteen feet to left, and 400 fired eight feet to right of center of target); hits, 4,361.
2,000	Oct. 4, 1878	......do	Target No. 2: Fired at 200-yard target (1,000 fired three feet to right of center, and 1,000 fired six feet to left of center of target); hits, 3,595.
2,000	Oct. 4, 1878	......do	Target No. 3: Fired at 250-yard target (1,000 fired five feet to right of center, and 1,000 fired five feet to left of center of target); hits, 2,382.
2,000	Oct. 4, 1878	......do	Target No. 4: Fired at 300-yard target; hits, 1,571.
1,600	Oct. 4, 1878	......do	Target No. 5: Fired at 200-yard target; hits, 2,650.
9,600			

NOTE.—Two cartridges failed to explode; one due to four balls and no powder, and the other no vent through cup.

[Third indorsement.]

ORDNANCE OFFICE, *October* 17, 1878.

Respectfully referred to the commanding officer Frankford Arsenal for the information of Captain Wright.

S. C. LYFORD,
Acting Chief of Ordnance.

[Fourth indorsement.]

FRANKFORD ARSENAL, PA.,
October 18, 1878.

Respectfully referred to Capt. E. M. Wright for his information.

J. M. WHITTEMORE,
Major of Ordnance, Commanding.

[Fifth indorsement.]

FRANKFORD ARSENAL, PA.,
October 25, 1878.

Respectfully returned to the commanding officer Frankford Arsenal.

The targets obtained at Sandy Hook were not as good as they should have been. Experiments conducted since the trial there show that almost any result can be obtained by varying the kind of powder or the amount of charge used.

In my original experiments I used the service Hazard powder, giving a velocity of 1,320 feet. At Sandy Hook the powder was Dupont's service of 1,360 feet, and scattered the bullets too much.

I inclose herewith three targets at 100, 200, and 300 yards (see Plate VI), which are from 25 to 100 per cent. better than the corresponding ones made at Sandy Hook, and would respectfully request a further trial with such number as the department may deem proper.

E. M. WRIGHT,
Captain of Ordnance.

[Sixth indorsement.]

FRANKFORD ARSENAL, PA.,
October 26, 1878.

Respectfully returned to the Chief of Ordnance, United States Army.

I see no reason why the results obtained by Captain Wright, and referred to in the preceding indorsement, cannot be reproduced at any time if desired.

J. M. WHITTEMORE,
Major of Ordnance, Commanding.

[Seventh indorsement.]

ORDNANCE OFFICE, *October* 28, 1878.

Respectfully returned to the Ordnance Board.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

[Eighth indorsement.]

THE ORDNANCE BOARD, *October* 29, 1878.

Respectfully returned to the Chief of Ordnance, recommending that Captain Wright be allowed the additional trial desired, and that the commanding officer Frankford Arsenal be instructed to make and send to Sandy Hook, for this trial, 10,000 cartridges.

S. CRISPIN,
Bvt. Col. U. S. A., Lt. Col. of Ordnance, President of the Board.

[Ninth indorsement.]

ORDNANCE OFFICE, *October* 31, 1878.

Respectfully referred to commanding officer Frankford Arsenal, who will make 10,000 rounds and send them to Sandy Hook, this paper to be forwarded to the Ordnance Board.

In the next trial the Board will determine the maximum distance at which a ball, of the multiball cartridge, will be effective, and the percentage of balls in the target at the maximum distance.

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

[Tenth indorsement.]

FRANKFORD ARSENAL, PA., *November* 25, 1878.

Respectfully forwarded to the Ordnance Board. Ten thousand multiball cartridges, cal. .45, Wright's, will be shipped by rail to Lieut. W. S. Starring, Sandy Hook, N. J., to-morrow.

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

[Eleventh indorsement.]

THE ORDNANCE BOARD U. S. A.,
New York, December 30, 1878.

Respectfully returned to the Chief of Ordnance U. S. A., together with record of firings and target plottings made at Sandy Hook November 29 and 30. (See Plates VII, VIII, IX, X, XI, XII, and XIII.) The record shows that up to and including 300 yards the destructive effect is very great, and exceeds that obtained with canister, and is more than one-half greater than that obtained in any mitrailleurs using the ordinary ammunition. Three hundred yards the board considers the maximum effective distance for the multiball cartridge, at which range there were 1,683 hits for the 1,000 rounds fired, or $56\frac{1}{10}$ per cent. of hits for the 3,000 balls thrown. Of the 1,683 hits, only 50 per cent. of the balls went through the target.

S. CRISPIN,
Bvt. Col. U. S. A., Lt. Col. of Ordnance, President of the Board.

Record of firing with Wright's multiball cartridges, fired at Sandy Hook, New York Harbor, from November 29 to November 30, 1878, from Gatling gun, caliber 0".45.

Number of rounds.	Date.	Ammunition.	Elevation in degrees.	Remarks.
1,000	Nov. 29, 1878	Wright's multiball cartridges; charge, 45 grains; each cartridge containing three balls weighing 133 grains each.	......	Fired at 100-yard target; gun oscillating; number of hits in target, 2,801; 320 fired fifteen feet to left of center, 360 two feet to left, and 320 fired fourteen feet to right of center; target, 10 by 32 feet, made of 1-inch spruce boards.
1,000	Nov. 29, 1878	......do	......	Fired at 150-yard target; gun oscillating; number of hits in target, 2,644; 240 fired thirteen feet to left of center, 240 five feet to left, 280 six feet to right, and 240 fired fourteen feet to right of center; target, 10 by 52 feet, made of 1-inch spruce boards.
1,000	Nov. 29, 1878	.... do	......	Fired at 200-yard target; gun oscillating; number of hits in target, 2,582; 320 fired nine feet to left of center, 360 six feet to right and 320 fired nineteen feet to right of center; target, 12 by 52 feet, made of 1 inch spruce boards.
1,000	Nov. 30, 1878	......do	$1\frac{1}{6}$	Fired at 250-yard target; gun oscillating; number of hits in target, 2,017; 490 fired seven feet to left of center and 510 fired sixteen feet to right of center; target, 12 by 52 feet, made of 1 inch spruce boards.
1,000	Nov. 30, 1878	......do	$1\frac{1}{8}$	Fired at 300-yard target; gun oscillating; number of hits in target, 1,683; 50 per cent. not through; 490 fired two feet to left of center and 510 fired sixteen feet to right of center; target, 14 by 52 feet, made of 1-inch spruce boards.
1,000	Nov. 30, 1878	.... do	$2\frac{1}{4}$	Fired at 350-yard target; gun oscillating; number of hits in target, 1,170; 10 per cent. through; target, 14 by 52 feet, made of 1-inch spruce boards; all fired ten feet to right of center.
1,000	Nov. 30, 1878	......do	$3\frac{3}{8}$	Fired at 400-yard target; number of hits in target, 768; 3 per cent. through; target, 14 by 52 feet, made of 1-inch spruce boards; all fired eight feet to right of center.

NOTE.—Gun worked well during the entire firing; no trouble feeding or extracting cartridges.

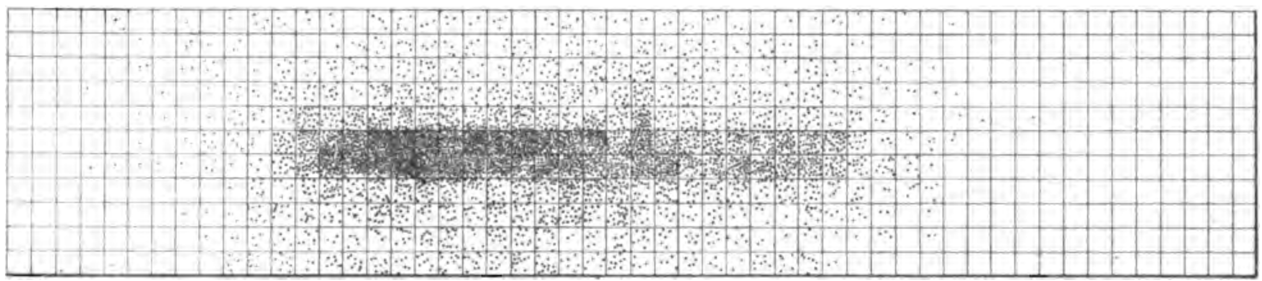
PLATE I.

TARGET RECORD. 10 BARREL GATLING GUN, CAL. .45 INCH. WRIGHT'S MULTIBALL CARTRIDGE.

At Sandy Hook, N. J., October 3rd, 1878.

Target 100 Yards from Gun.

Number of Rounds Fired, 2,000. *Number of Hits in Target, 4,361.*



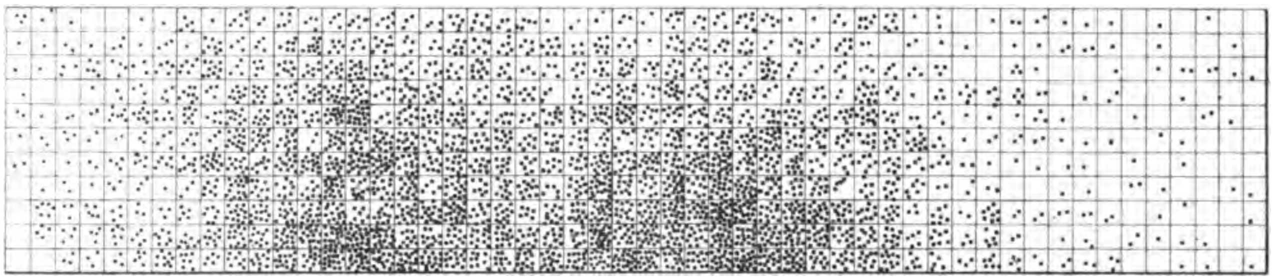
Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.) *Number of Balls in Each Cartridge, 3.*

TARGET RECORD. 10 BARREL GATLING GUN. CAL, .45 INCH. WRIGHT'S MULTIBALL CARTRIDGE.

At Sandy Hook, N. J., October 4th, 1878.

Target 200 Yards from Gun.

Number of Rounds Fired, 2,000. *Number of Hits in Target, 3,595.*



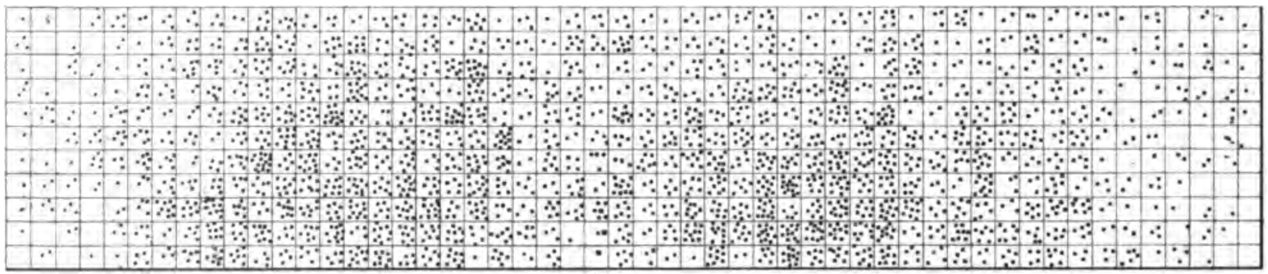
Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.) *Number of Balls in Each Cartridge, 3.*

TARGET RECORD. 10 BARREL GATLING GUN, CAL. .45 INCH. WRIGHT'S MULTIBALL CARTRIDGE.

At Sandy Hook, N. J., October 4th, 1878.

Target 250 Yards from Gun.

Number of Rounds Fired, 2,000. *Number of Hits in Target, 2,382.*



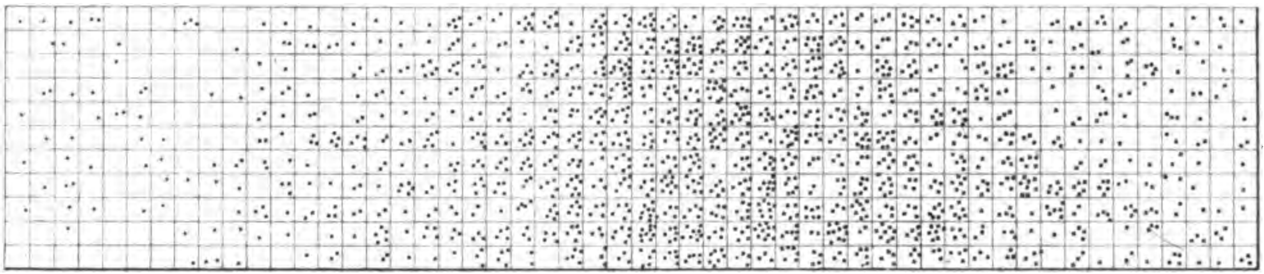
Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.) *Number of Balls in Each Cartridge, 3.*

TARGET RECORD. 10 BARREL GATLING GUN, CAL. .45 INCH. WRIGHT'S MULTIBALL CARTRIDGE.

At Sandy Hook, N. J., October 4th, 1878.

Target 300 Yards from Gun

Number of Rounds Fired, 2,000. *Number of Hits in Target, 1,571.*



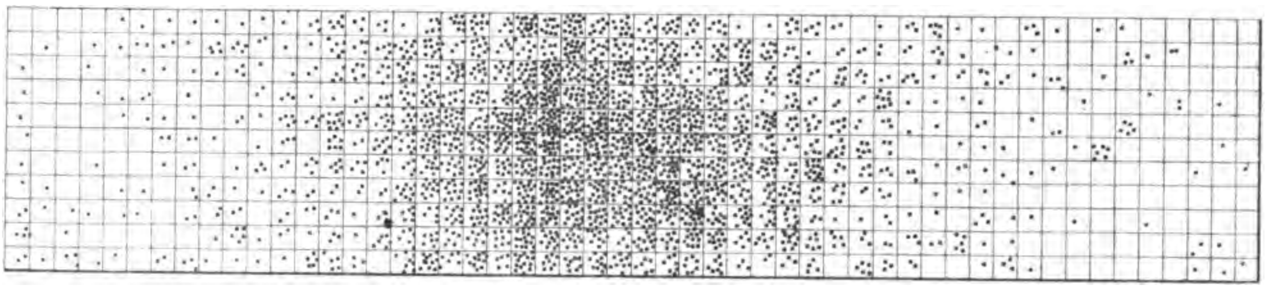
Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.) *Number of Balls in Each Cartridge, 3.*

TARGET RECORD. 10 BARREL GATLING GUN, CAL. .45 INCH. WRIGHT'S MULTIBALL CARTRIDGE.

At Sandy Hook, N. J., October 4th, 1878.

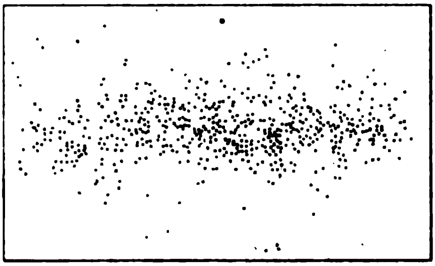
Target 200 Yards from Gun.

Number of Rounds Fired, 1,600. *Number of Hits in Target, 2650.*



Target 11 × 52 Feet. Made of Spruce Boards. (1 inch.) *Number of Balls in Each Cartridge, 3.*

TARGET 20 Feet long, 12 Feet high. — Distance 100 Yards.



200 Multiball Cartridges fired from Gatling Gun, using oscillator.

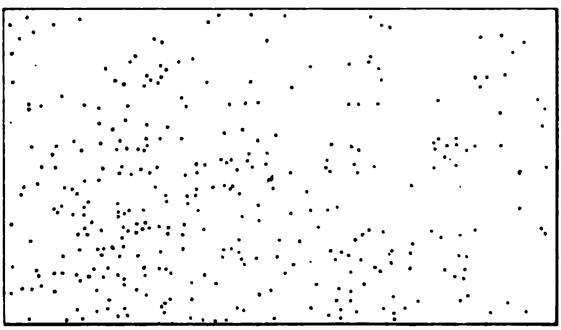
200 SHOTS. ——— 580 HITS. ——— 100 YARDS.

TARGET 20 Feet long 12 Feet high. — Distance 200 Yards.

200 Multiball Cartridges fired from Gatling Gun, using oscillator.

200 SHOTS. ——— 502 HITS. ——— 200 YARDS.

TARGET 26 Feet long 15 Feet high. — Distance 300 Yards.



200 Multiball Cartridges fired from Gatling Gun, using oscillator.

200 SHOTS. ——— 331 HITS. ——— 300 YARDS.

Point aimed at, Centre of Target.

Appendix 1st Report of Chief of Ordnance, 1879

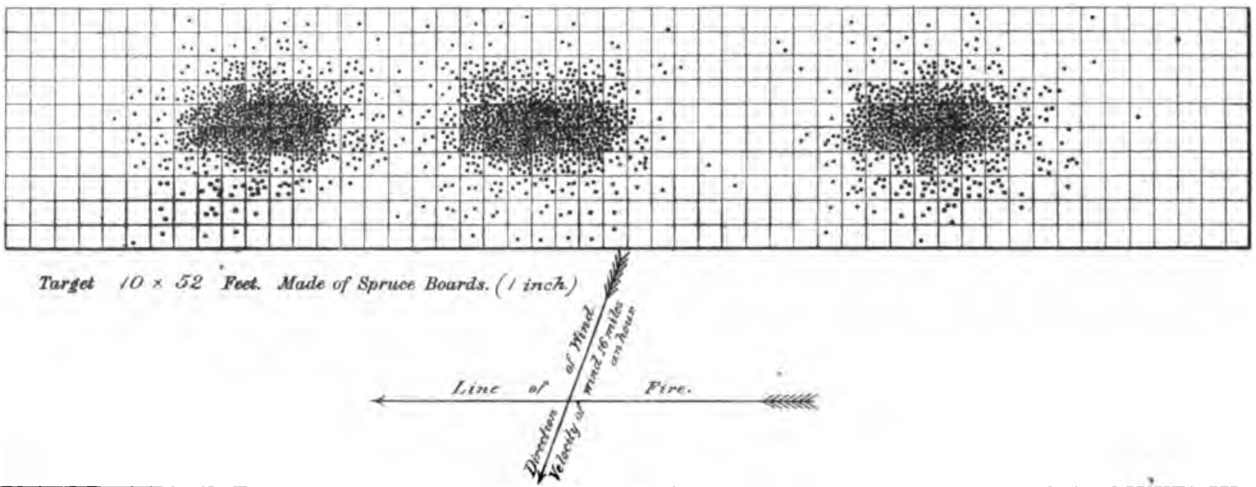
TARGET RECORD. WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N. J., November 29th, 1878.

Target 100 Yards from Gun.

Charge of Powder, 45 Grains. *Number of Balls in Each Cartridge, 3.*

Number of Rounds Fired, 1000. *Number of Hits in Target, 2801.*



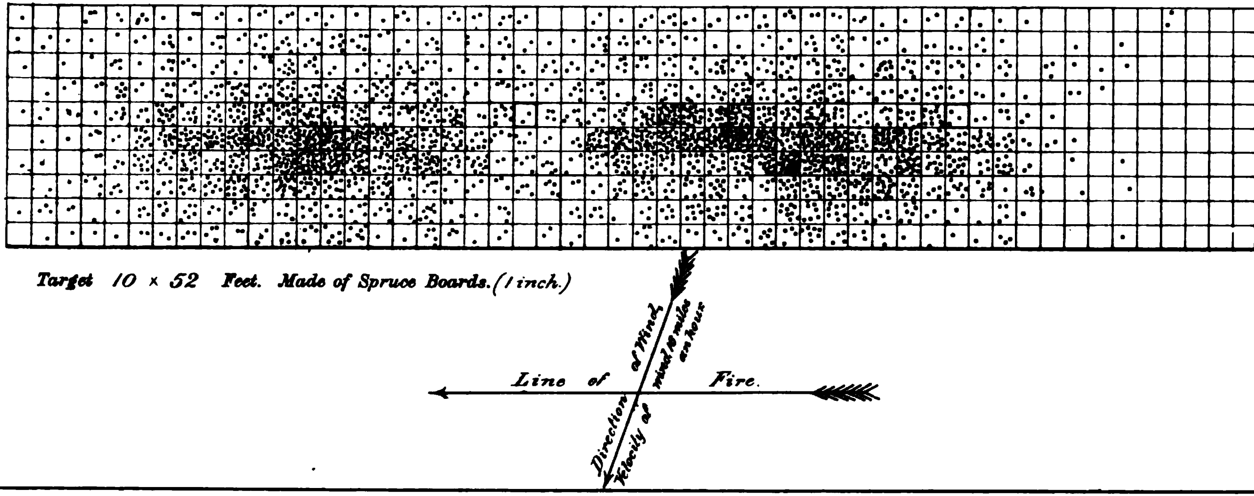
TARGET RECORD WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N. J., November 29th, 1878.

Target 150 Yards from Gun.

Charge of Powder, 45 Grains. Number of Balls in Each Cartridge, 3.

Number of Rounds Fired, 1,000. *Number of Hits in Target, 2644.*



Target 10 × 52 Feet. Made of Spruce Boards. (1 inch.)

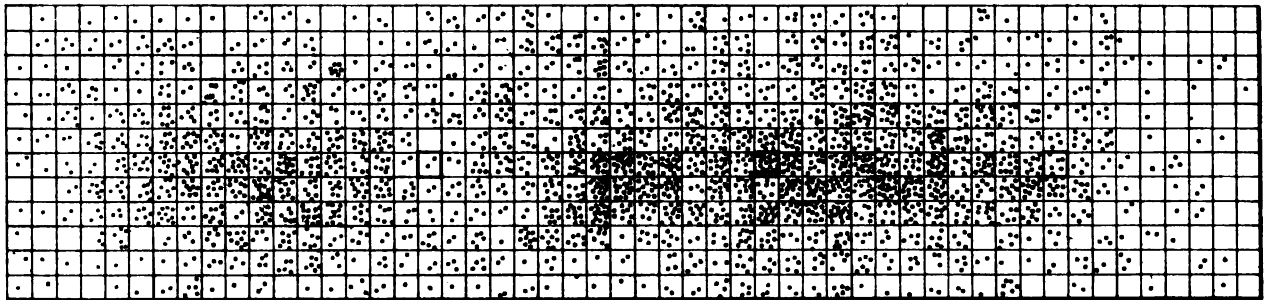
TARGET RECORD. WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N. J., November 29th, 1878.

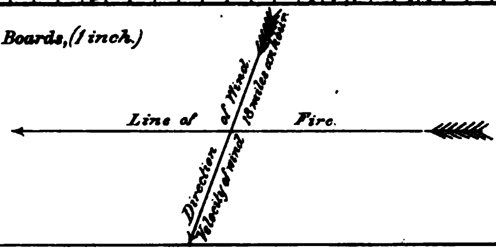
Target 200 Yards from Gun.

Charge of Powder, 45 Grains. *Number of Balls in Each Cartridge, 3.*

Number of Rounds Fired, 1,000. *Number of Hits in Target, 2,582.*



Target 12 × 52 Feet. Made of Spruce Boards, (1 inch.)



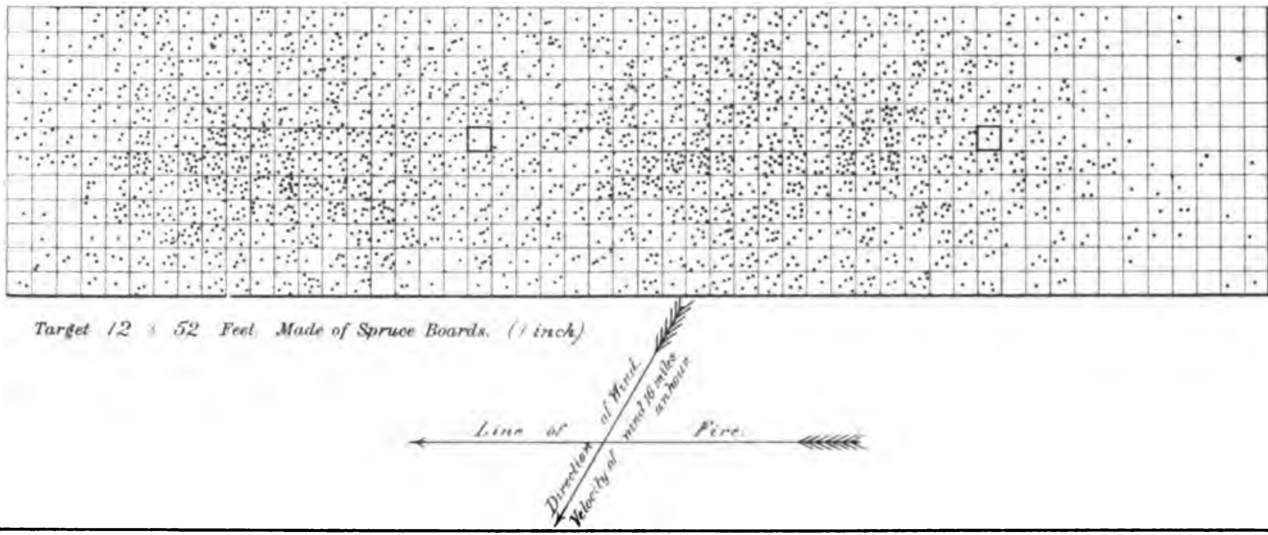
TARGET RECORD. WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N. J., November 30th, 1878.

Target 250 Yards from Gun.

Charge of Powder, 45 Grains. *Number of Balls in Each Cartridge, 3.*

Number of Rounds Fired, 1,000. *Number of Hits in Target, 2,017.*



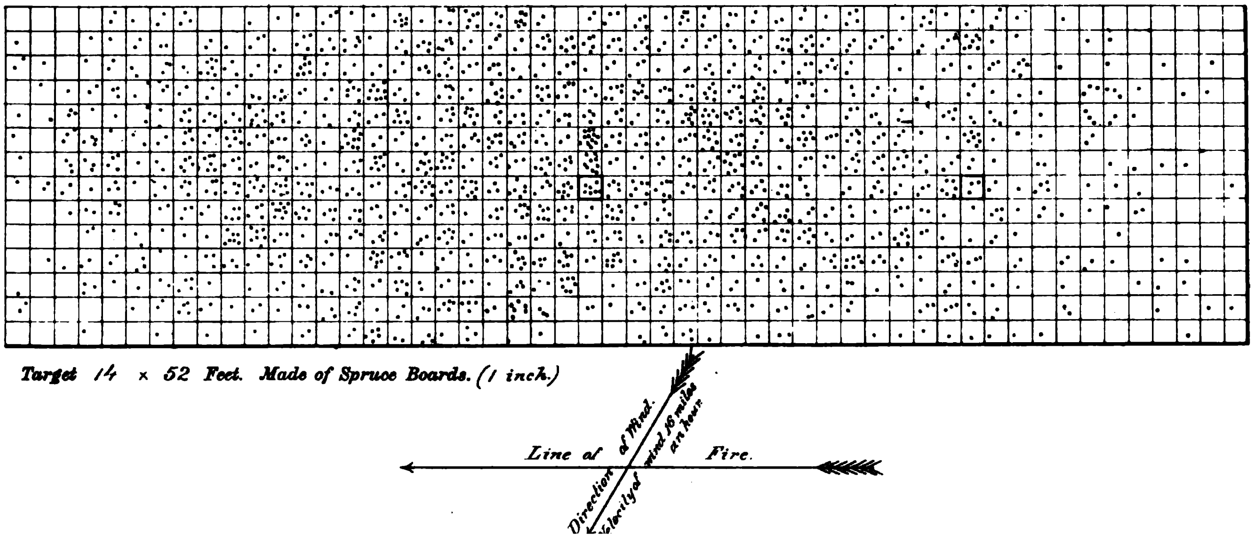
TARGET RECORD. WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N. J., November 30th, 1878.

Target 300 Yards from Gun.

Charge of Powder, 45 Grains. *Number of Balls in Each Cartridge, 3.*

Number of Rounds Fired, 1,000. *Number of Hits in Target, 1,683.*



Target 14 × 52 Feet. Made of Spruce Boards. (1 inch.)

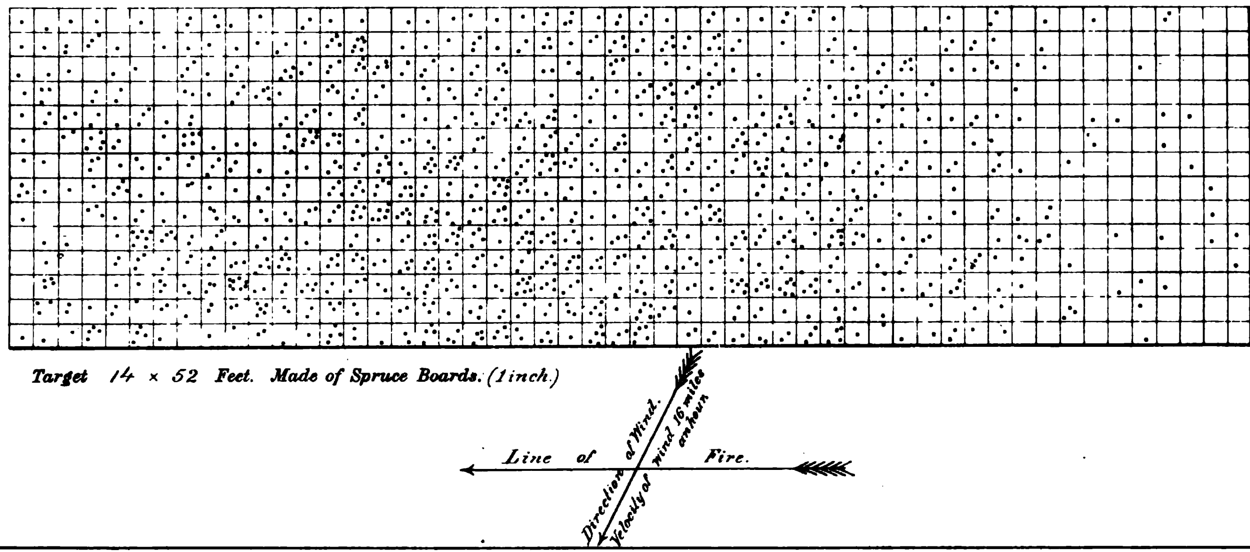
TARGET RECORD. WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N. J., November 30th, 1878.

Target 350 Yards from Gun.

Charge of Powder, 45 Grains. *Number of Balls in Each Cartridge, 3.*

Number of Rounds Fired, 1,000. *Number of Hits in Target, 1,170.*



Target 14 × 52 Feet. Made of Spruce Boards. (1 inch.)

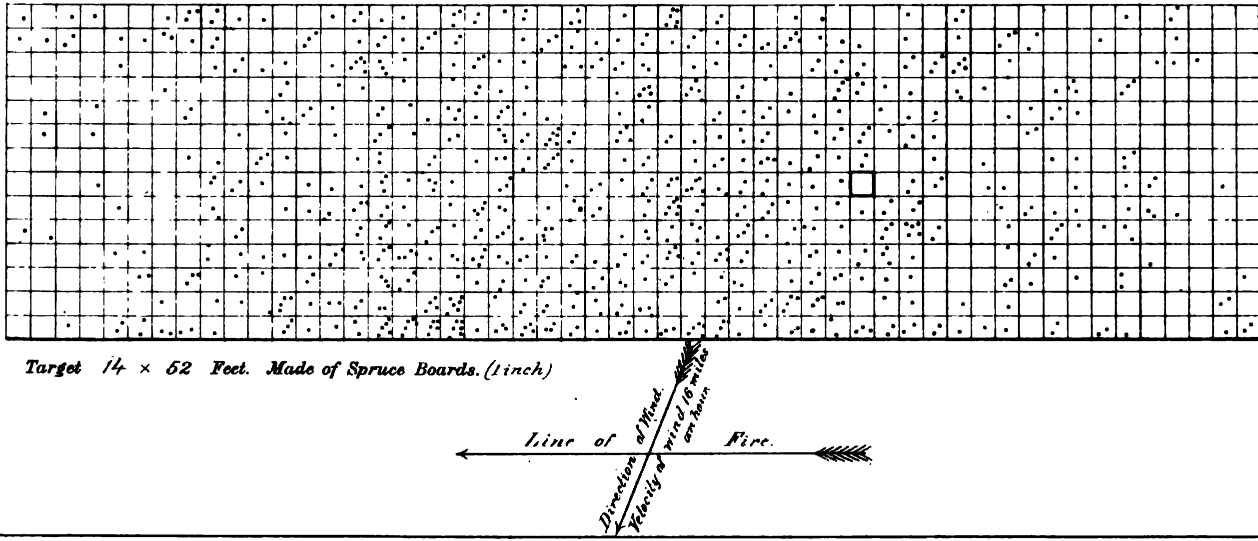
TARGET RECORD. WRIGHT'S MULTIBALL CARTRIDGE, CAL. .45 INCH. FIRED FROM GATLING GUN.

At Sandy Hook, N J., November 30th, 1878.

Target 400 Yards from Gun.

Charge of Powder, 45 Grains. *Number of Balls in Each Cartridge, 3.*

Number of Rounds Fired, 1,000. *Number of Hits in Target, 768.*



Target 14 × 52 Feet. Made of Spruce Boards. (1 inch)

APPENDIX K.

REPORT OF THE PRINCIPAL OPERATIONS AT ROCK ISLAND ARSENAL DURING THE FISCAL YEAR ENDED JUNE 30, 1879; MAJOR D. W. FLAGLER, ORDNANCE DEPARTMENT, COMMANDING.

(Nine plates.)

SHOP G.

An iron working and finishing shop for the arsenal.

During the fiscal year the basement story of this shop has been built and the first story above the basement has been nearly completed. The iron beams for one-half of the first floor have been purchased, and all the iron for the floor fitted and put in position. All the iron bases for the first floor and iron columns for the first story have been made and fitted in the arsenal shops, and all the iron beams for the second floor have been purchased and are now being fitted. About one-sixth of the stone required for the second story has been purchased, and nearly all of the expensive entablature for the third story has been purchased and is now being cut.

All of the lumber required for the building (except the floors) has been purchased and stacked for seasoning, and about one-half of the doors, door-frames, window-sash, and window-frames, have been made in the arsenal shops. All of this work has progressed satisfactorily, except that serious and vexatious delays have occurred in procuring from the *Grafton Quarry Company* sufficient quantities of stone when required.

SHOP I.

A wood-working and leather-working shop for the arsenal.

This shop was begun during the year. It is the last shop to be built that is included in the plans for the arsenal. Excavations for the building and for foundations were begun in July, 1878. The difficulties met in procuring suitable foundations for shops F and G, and which have been described in previous annual reports, were again encountered in procuring foundations for this shop. Nearly all the foundations are built on the peculiar, tough, indurated clay which has been described in previous reports. The examinations and trials of this clay gave rather better results than in the case of shops F and G, and the foundations are satisfactory.

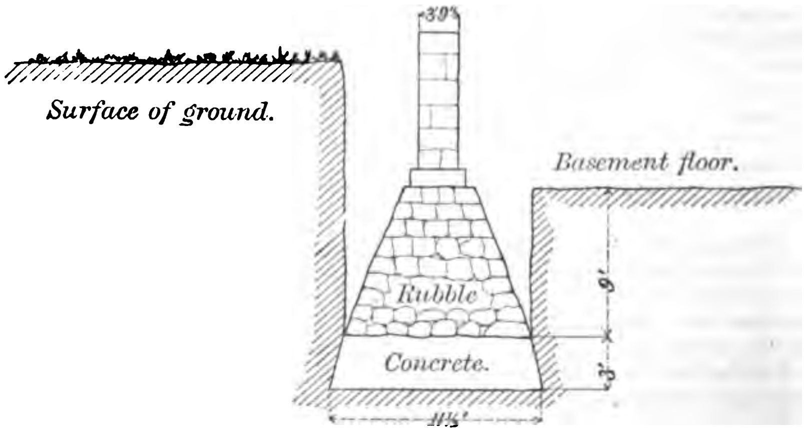
The depth of the excavations for foundations below the floor of the basement averaged about 13 feet, and extended, in all cases, 3 feet in the bed of clay described.

The bed of clay was fully examined to determine whether it was good and uniform throughout, by drilling holes through it to the rock below at intervals of about 30 feet.

The average depth to the rock below was about 20 feet, and about 30 feet from the level of the basement.

The foundations were made from 11 to 12 feet wide at the bottom; the excavation in the clay, 3 feet deep and about 11½ feet wide, being wholly

filled with carefully-rammed concrete. From the top of this the foundation walls are built of rubble and cement-mortar, battered on both sides till they are 5 feet wide at the level of the basement floor. At this point the footing stones, 4½ feet wide, were laid, and on these were laid the main walls of the building.



The unfilled part of the excavation between the rubble walls and the bank was then filled with the clay that had been excavated, which was well rammed to protect the walls from water. The bed of clay is itself impervious to water, and the excavation in it being filled with rammed concrete, the bottom of the foundation is thoroughly protected from the action of water. The foundations for the 76 floor-piers are of the same character, and were built in the same way. They are generally 11½ feet square at the bottom.

The total amount of masonry in the foundations (below the basement floor) in this building is 5,574 cubic yards, about 80 per cent. of the amount in the walls above ground. The foundations are all laid in cement-mortar, and cost $2.33 per yard. The stone was dug from the piles of earth and rock taken out of the water-power canal some years ago. It was ferried across the water-power pool, and hauled to the building in wagons at a cost of 56 cents per yard, about 22 cents per ton.

Derricks and new mechanical devices were employed to lessen the cost of putting in the foundations, and the cost of the work is exceedingly low.

Plate I shows all the excavations and foundations as constructed, and positions and depth of some of the borings made to examine strata below the foundations.

The stone required for the walls of this building is brought from Anamosa, Iowa, and is furnished by Mr. J. A. Green under contract. This stone has already been used in the construction of one set of quarters, and the Post building, on Main avenue; but was not adopted for this shop until after very careful tests had been made, and trials, extending through several years, to determine its durability when exposed to water, frost, and the weather.

It coincides closely in appearance with the stone used in the other shops, is believed to be more durable, and, although less handsome when new, the thick ledges used give a more massive appearance to the walls; and, as the stone grows brighter with exposure and age, it is believed

that it will make as handsome a building as any of the others. The price paid is a low one, and the stone can be cut cheaper than the Joliet stone used in the other shops.

The stone has been furnished promptly and satisfactorily, and work on the building has progressed rapidly as far as the limited appropriation would permit.

Besides the completion of the excavations and foundations, the basement story has been built entire; the iron beams for the first floor purchased, fitted, and put in place; the cast-iron bases for the first floor cast, fitted, and put in, and about one-half the stone for the first story has been purchased, cut, and prepared for setting. The cost of the portion of this building completed at the present time has been about one-half the cost of the same amount of work on other buildings seven years ago.

SHOP H.

An iron-foundery shop for the armory.

This shop was also begun during the year. It is the last shop but one (K not begun) included in the plans for the armory. Excavations for the building and the foundations were commenced in August, 1878. The excavations for the building have been completed, and the excavations for foundations of about two-thirds of the walls completed and the foundations put in.

Plate II shows this work fully. The character of the strata excavated, the foundations obtained, and method of constructing them are about the same for nearly all of the buildings as in shop I, just described, and further description of them is unnecessary.

In the plat of the building, the full black line shows the foundations that have been put in; the dotted line shows the parts that have not been put in.

A special description is required of the difficulties encountered in getting suitable foundations in the part marked *b c* on the plat.

There was a pocket in the rock at this point, similar to those found under shops D and G, described in annual reports for the fiscal years ending June 30, 1872 and 1878. This new pocket was deeper and the difficulties which had to be overcome in getting secure foundations were more serious than in any previous case. This pocket, and the form and dimensions of the excavation, in the direction of the walls of the building, are shown at *b c* on the geological chart. Special drawings on a larger scale, Figures 2 and 3, show more fully the form of the excavation and the masonry put in.

The total depth of the excavation below the basement floor was 62 feet, making the total depth from the surface of the ground 67 feet.

The strata passed through were generally a soft, unstable mixture of clay and various earths, alternating with loose masses of rock, and in some places points of poor, solid rock projected into the excavation. These last had to be removed even when sound, to permit putting in secure sheathing, and also to permit hoisting out the materials excavated below. This could be accomplished only by drilling and wedging, as blasts could not be used without destroying the sheathing. The same means had to be employed in breaking up the loose masses of rock into fragments that could be hoisted out.

A great difficulty was to construct sheathing of sufficient strength to resist the pressure of the loose, sliding masses of rock that were passed

in going down. It would occur that where this pressure was greatest, there would be little or nothing in the opposite bank to resist it.

The ooze or wash of the soft clay through the sheathing sometimes left vacant places behind the sheathing till caving in filled them up.

After passing below the water-level of the river, the inflow of water, which seems to make its way through passages in the rock, was very great. Steam-pumps were used, but only small pumps could be accommodated because of the small spaces among the sheathing timbers and the necessity for shifting and lowering them, and refitting pipes frequently.

The sand pumped through them cut the cylinders and destroyed the packing so quickly that the latter required renewing generally every day. From one to three small steam-pumps were employed, and one or two kept at work constantly, discharging generally about 180 gallons per minute.

The men that were digging had generally to stand in from one to two feet of water. The materials were hoisted out by steam-power. Good sound rock foundation was finally obtained.

The masonry put in is partially shown in Figures 2 and 3. It was, generally, alternate layers of concrete and good Joliet rubble-stone masonry, tied together in places with large footing stones. The masonry was further supported in places by arches butting into solid rock at the sides.

Seven weeks were consumed in excavating and filling this pocket, and 402 cubic yards of masonry were used. The pumps were used while putting in the masonry, yet much of the concrete had to be laid in water. Gangs of men were employed at night and out of working hours a portion of the time. Much credit is due to Mr. W. A. P. Totten, foreman of laborers, who had charge of the excavation and sheathing, and to Mr. Robert McFarlane, who put in the masonry, for the ability, good sense, and devotion to the work displayed by them.

A total of 4,647 cubic yards of masonry was put into the foundations of this shop, and about one-third of the foundations and all the piers have yet to be put in.

The other work done on this building has been the purchase of about one-half the stone required for the basement story. This stone has been cut and about one-half of it set in the walls of the west wing. A contract for the stone was made with Mr. Edwin Walker, of Lemont, Ill. The stone in Mr. Walker's quarries is precisely the same as the Joliet stone used in the other shops. Mr. Walker's shipments of stone were very dilatory and unsatisfactory till in May, 1879, when he commenced procuring his stone from Messrs. Sanger & Moody's quarries, at Joliet, Ill. The latter parties have shipped the stone promptly, of excellent quality, and in quantities as required. The Chief of Ordnance has now, by authority of the Secretary of War, directed that Mr. Walker's contract be annulled, and that a new contract be made for the ensuing year with Messrs. Sanger & Moody.

MACHINERY AND SHOP FIXTURES.

The principal work done under this head during the year has been—

1st. The completion of the machinery and fixtures in shop F (the armory rolling-mill), as per special authority of the Chief of Ordnance, dated February 25, 1878.

2d. The completion and erection of the experimental and temporary line of wire-rope transmission of power to a portion of the arsenal shops,

for use pending the construction of the rest of the shops, and the completion and putting in of water-wheels, pen-stocks, and machinery at the water-power dam.

3d. The main lines of shafting for the first and second stories of shop A, have been manufactured and put up—four lines of 300 feet each.

Most of the machinery and fixtures for the rolling-mill had been purchased and manufactured during the preceding year, but as very little of it had been put in, no report upon the same was made in my last annual report. These fixtures and their machinery are shown on Plate III, transmitted herewith.

The boilers are divided into two batteries of two boilers each, and the details of the plant are shown on Plates V, VI, VII, IX.

The boiler fronts and all the fittings and fixtures were manufactured in the arsenal shops. The four boilers are each 18 feet long and 44 inches interior diameter, with 22 4-inch diameter tubes. They are made of ¼-inch U. S. iron. The iron was manufactured in Pittsburgh, Pa., but was purchased, inspected, and tested, and the boilers made here. They are calculated to have sufficient steam capacity, at 80 pounds pressure, to furnish steam for 250 horses power, in first-class engines, cutting off at ⅛ stroke, and the plant and all its fittings are the very best that could be built. The engine is a single horizontal non-condensing engine, with the Bartlett automatic cut-off, made by the Putnam Machine Company, at Fitchburg, Mass., and has 200 horses power, with 80 pounds pressure, cutting off at ⅛ stroke. (See Plate IV.)

The countershaft *c*, on Plates III and IV, is a part of the main line of armory shafting, which is to be driven eventually by the water-power. (See main line M′ R′ on Plate I, accompanying my special report on machinery for water-power and transmission, sent to the Chief of Ordnance April 8, 1874.) This arrangement is to permit the use of the engine to aid the water-power or to permit the use of the engine to run any of the armory shops alone when the water-power may not be in use. The engine should furnish alone sufficient power for the manufacture of about 500 muskets per day.

The train of rolls is a 14-inch, two high train adapted to the manufacture of ordinary forms of bar-iron required for ordnance purposes from the wrought scrap that may accumulate at the arsenal from time to time.

The furnace (marked *f* on Plate III) is of special pattern, and is arranged to burn its smoke. It is driven by a fan located at *g*.

The 5,000 pounds steam-hammer, located at *h*, is adapted for "shingling," and making hammered blooms, in connection with the mill, for the manufacture of special high grades of iron, from scrap, for ordnance purposes. It is also adapted, in connection with the furnace, to the manufacture of any heavy forgings that the probable future wants of the government may ever require at this place, and especially to the manufacture from scrap of the large quantities of heavy and expensive shafting required for the shops and transmission of power, some of which are 9 inches diameter.

The shear is marked *k* on Plate III. It is a second-hand alligator shear, procured at about the price of old scrap, and is specially adapted to cutting up scrap and bar for piling for the mill, but has sufficient power for cutting gun-carriage axles and any heavy job work that future operations of the arsenal may require.

The saw, marked *m*, on Plate III, is for cutting large bar hot. It was made at the arsenal.

The mill has been run about four weeks, during which time 6,000 feet

of T rail, 25 pounds per yard, were made from miscellaneous scrap for immediate use for derrick and tram-tracks in the construction of the shops, and is adapted for permanent tram-tracks required in and about the shops in the future; 11,000 pounds of ordinary round bar, required for general use in connection with building operations, and 12,000 pounds of round bar, miscellaneous sizes, of a high grade of hammered bloom-iron from selected gun-carriage and old horseshoe scrap, for the roof frame of shop G. The tests of this latter iron were very satisfactory, and show a better quality for the purpose required than any the government has been able to purchase for the same purpose. The results of the tests for permanent set and elasticity of one average bar are given below:

Sample No. 4.

From horseshoe-bloom, hammered, cooled, reheated, and rolled direct to 1-inch round.

[Tested for permanent set, extensions, and restorations. Diameter of sample, 0.798 inch. Reading before strain, 0.0211 inch. Length between shoulders, 10 inches. Area, 0.498 inch.]

Load, pounds.	Reading, under strain.	Reading, strain removed.	Extension, per inch.	Restoration, per inch.	Load, per square inch.	Stretch, per inch.
5, 000	0. 0242	0. 0211	0. 00031	Complete ...	10, 000	0. 00000
6, 000	0. 0256	....	0. 00045	....	12, 000	0. 00000
7, 000	0. 0261	....	0. 00050	....	14, 000	0. 00000
8, 000	0. 0272	....	0. 00061	....	16, 000	0. 00000
9, 000	0. 0282	....	0. 00071	....	18, 000	0. 00000
10, 000	0. 0292	....	0. 00081	....	20, 000	0. 00000
11, 000	0. 0302	....	0. 00091	....	22, 000	0. 00000
11, 500	0. 0307	0. 0213	0. 00096	0. 00094	*23, 000	0. 00002
12, 000	0. 0312	0. 0215	0. 00101	0. 00097	24, 000	0. 00004
12, 500	0. 0317	0. 0217	0. 00106	0. 00100	25, 000	0. 00006
13, 000	0. 0322	0. 0219	0. 00111	0. 00103	26, 000	0. 00008
13, 500	0. 0327	0. 0221	0. 00116	0. 00106	27, 000	0. 00010
14, 000	0. 0332	0. 0222	0. 00121	0. 00110	28, 000	0. 00011
14, 500	0. 0337	0. 0223	0. 00126	0. 00114	29, 000	0. 00012
15, 000	0. 0341	0. 0224	0. 00130	0. 00117	30, 000	0. 00013
15, 500	0. 0345	0. 0225	0. 00134	0. 00120	31, 000	0. 00014
16, 000	0. 0349	0. 0225	0. 00138	0. 00124	32, 000	0. 00014
16, 500	0. 0353	0. 0226	0. 00142	0. 00127	33, 000	0. 00015
17, 000	0. 0358	0. 0226	0. 00147	0. 00132	34, 000	0. 00015
17, 500	0. 0363	0. 0227	0. 00152	0. 00136	35, 000	0. 00016
18, 000	0. 0405	0. 0285	0. 00194	0. 00120	*36, 000	0. 00074
19, 000	0. 140	0. 128	0. 01189	0. 00120	38, 000	0. 01069
20, 000	*0. 288	0. 256	0. 02669	0. 00320	40, 000	0. 02349
21, 000	0. 368	0. 350	0. 03469	0. 00130	42, 000	0. 03339
26, 800	....	....	0. 1875	....	53, 600	0. 18750

*Broke. Diameter of fracture, 0.73 inch.

Notes.—The readings show that the restoration was not quite perfect between 23,000 pounds and 36,000 pounds per square inch. I find it not possible to avoid slight errors in using the gauge, and the principal source of error is a slight abrasion of the iron of the sample by repeated rubbing pressures of the steel gauge. This is so slight as to be an unimportant error in the extensions, but may be sufficient to show an imperfect restoration and a slight permanent set, when the restoration was perfect and no permanent set occurred.

In this case stretch indicated at 23,000 pounds was only $\frac{2}{100000}$ of an inch in one inch of length, and at 36,000 had only increased to $\frac{16}{100000}$. Even if this or a portion of it is not due to the abrasion mentioned, the stretch is so slight as to show that no injury was done to the iron until appreciable permanent set occurred at 36,000 pounds, and shows an iron of very remarkable elasticity.

The record also shows a remarkable uniformity in the increase of the extensions and restorations as the load was increased. From 7,000 to

11,000 pounds (on the sample) the increase of extension is exactly $\frac{10}{10000}$ for every increase of 1,000 pounds of load. From 11,000 to 15,000 pounds it is exactly $\frac{3}{10000}$ for every increase of 500 pounds. After that the increase is less, but perfectly regular, till the sample began to stretch and give way at 18,000 pounds (about 36,000 pounds per square inch). The restorations and slight indicated stretch are quite as uniform.

A sample from this same bar was heated by a smith, bent back on itself and welded, then chilled suddenly in cold water, and the welded bar 1 inch square was then bent double, cold, and hammered flat without cracking.

The water-wheels and water-power machinery put in and the temporary line of wire-rope transmission put up, were made exactly in accordance with the plans and drawings sent to the Chief of Ordnance April 8, 1874, with the special report on machinery for the water-power and transmission. As the experience gained in the use of this line should be included in a revision of the above report, to be made hereafter, no report of it is made here.

Four water-wheels with all the necessary appointments, pen-stocks, houses, and machinery were put in, and the water-wheels and machinery and the whole line of transmission were manufactured in the arsenal shops.

The four wheels furnish about 250 horses power. The work was completed and the line of transmission attached to arsenal shops C and E, February 1, 1879. Since that date the shops have been driven continuously by the water-power, except during one week in April, when the wire ropes were shortened and re-spliced to take out their first stretch.

Both the water-power and the transmission have been satisfactory in all respects, and have furnished abundant and excellent power.

The four main lines of shafting put in shop A are each 300 feet long, and are all cold-rolled iron. Two of these are in the first story and are 3 inches in diameter, and two are in the second story and are $2\frac{1}{2}$ inches in diameter. These were finished and fitted in the arsenal shops, and all the hangers, boxes, couplings, and other fixtures were made in the arsenal shops. The patterns of these fixtures are the same as those in shop C, drawings of which were sent to the Chief of Ordnance with my annual report for the fiscal year ending June 30, 1874, except that the boxes have been altered to make them self-oiling, and arrangements added to remove surplus oil and gum from the shaft, and carry them to the oil-cistern. The patterns of all these fixtures are new and were devised here.

ROCK ISLAND BRIDGE.

Beside the ordinary repairs of the bridge, a new floor for the wagon-road has been put on the bridge during the year. This work was begun May 5 and completed June 4, 1879. It was a more difficult work than was anticipated.

Examinations of the floor timbers made two years ago, when the estimate for the work was made, showed a portion of the timbers to be in good condition, but when the floor was torn up all were found to have deteriorated more or less, and although one-half of them might have remained serviceable many years, the cost of tearing up to take out a timber in the future would have been so great that I deemed it wise economy to take them all out and put in new timbers throughout.

The sidewalks were also renewed. The floors of these are now laid with 3-inch pine plank. The floor of the roadway is laid with 4-inch white-oak plank.

Much care was taken to procure good sound lumber. The total amount used was 111,000 feet of oak and 172,000 feet of pine.

I had hoped to be able to arrange the work so that the bridge could be opened to the public at night while the work was in progress, but this was found to be impossible. The difficulties attending pushing the work rapidly to lessen the time that it should be closed were serious and added somewhat to the cost. From 50 to 70 men were employed on the work.

Some slight changes were made in the iron tramways to make them more convenient, and in the floors to give better ventilation around the timbers and save them from rotting. Also the arrangement of floors and coverings of the bottom chords of the bridge was changed to prevent the retention of water on, and the rusting of the iron work, as well as to give a better appearance to the bridge.

A statement of teams and persons crossing the bridge during the year is appended and marked A.

A statement marked B is appended hereto, showing the stages of water in the water-power pool and tail-races, and the head of water at the two dams during the year. The power has been good throughout the year.

A statement marked C is appended hereto, showing fabrications and other work done on ordnance and ordnance stores during the year.

APPENDIX A.

Abstract of record kept at the Rock Island bridge during the year.

PASSING NORTH.

Engines with trains	4,559
Engines without trains	119
Total engines	4,678
Passenger-cars	6,309
Freight-cars	91,195
Foot-passengers	172,637
Teams	120,209
Steamboats	918
Barges	369

PASSING SOUTH.

Engines with trains	4,568
Engines without trains	123
Total engines	4,691
Passenger-cars	6,315
Freight-cars	91,299
Foot-passengers	172,623
Teams	119,188
Steamboats	906
Barges	338
Rafts	401

(B.)

Record of stages of water at site of water-power.

1878.

Day of month.	July. Moline bridge.	July. Tail-race at Moline.	July. Head of water at the Moline water-power dam.	July. Pool at Sylvan water dam.	July. Tail-race below Sylvan water dam.	July. Head of water at the United States dam.	August. Moline bridge.	August. Tail-race at Moline.	August. Head of water at the Moline water-power dam.	August. Pool at Sylvan water dam.	August. Tail-race below Sylvan water dam.	August. Head of water at the United States dam.
	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.
1....	11.10	4.80+	6.30	11.45	3.60	7.85	12.00	4.90	7.10	12.20	4.60	7.60
2....	11.25	4.80+	6.45	11.50	3.70	7.80	11.90	5.	6.90	12.05	4.45	7.60
3....	11.20	4.80+	6.40	11.50	3.75	7.75	11.80	4.80+	7.00	12.00	4.30	7.70
4....	11.20	4.80+	6.40	11.45	3.65	7.80	11.70	4.80+	6.90	11.95	4.20	7.75
5....	11.00	4.80+	6.20	11.30	3.50	7.80	11.75	4.90	6.85	11.95	4.20	7.75
6....	11.00	4.80+	6.20	11.20	3.30	7.90	11.70	4.90	6.80	11.90	4.20	7.90
7....	10.90	4.80+	6.10	11.20	3.20	8.00	11.70	4.80+	6.90	11.80	4.10	7.70
8....	10.80	4.80+	6.00	11.05	3.10	7.95	11.50	4.80+	6.70	11.70	3.90	7.80
9....	10.70	4.80+	5.90	11.	3.00	8.00	11.40	4.80+	6.60	11.60	3.80	7.80
10....	10.70	4.80+	5.90	10.95	2.90	8.05	11.35	4.80+	6.55	11.50	3.70	7.80
11....	10.65	4.80+	5.85	10.90	2.75	8.15	11.25	4.80+	6.45	11.45	3.50	7.95
12....	11.10	4.80+	6.30	11.20	3.10	8.10	11.10	4.80+	6.30	11.25	3.40	7.85
13....	12.60	4.80+	7.80	12.75	4.80	7.95	10.90	4.80+	6.10	11.20	3.00	8.20
14....	13.40	5.60	7.80	13.65	6.10	7.55	10.80	4.80+	6.00	11.05	3.05	8.00
15....	13.30	6.50	6.80	13.55	6.50	7.05	10.70	4.80+	5.90	10.90	3.00	7.90
16....	13.40	6.80	6.60	13.60	6.70	6.90	10.70	4.80+	5.90	10.80	2.90	7.90
17....	13.60	7.00	6.60	13.85	7.00	6.85	10.55	4.80+	5.75	10.75	2.75	8.00
18....	13.45	6.80	6.65	13.65	6.75	6.90	10.40	4.80+	5.60	10.65	2.60	8.05
19....	12.90	6.40	6.50	13.05	6.25	6.80	10.40	4.80+	5.60	10.60	2.60	8.00
20....	12.45	5.95	6.50	12.65	5.70	6.95	10.75	4.80+	5.95	10.95	3.20	7.75
21....	12.10	5.30	6.80	12.40	5.30	7.10	10.50	4.80+	5.70	10.75	2.80	7.95
22....	11.90	5.55	6.45	12.05	5.15	6.90	10.70	4.80+	5.90	10.90	3.10	7.80
23....	11.90	5.30	6.60	12.00	5.05	6.95	10.60	4.80+	5.80	10.80	3.00	7.80
24....	11.80	5.30	6.50	11.95	4.85	7.10	10.50	4.80+	5.70	10.70	2.80	7.90
25....	11.70	5.35	6.45	11.85	4.65	7.20	10.40	4.80+	5.60	10.65	2.60	8.05
26....	11.70	4.80+	6.90	11.95	4.55	7.40	10.10	4.80+	5.30	10.30	2.85	7.95
27....	11.80	4.80+	7.00	12.00	4.45	7.55	9.90	4.80+	5.10	10.10	2.20	7.90
28....	12.	4.80+	7.20	12.20	4.55	7.65	9.80	4.80+	5.00	10.[illegible]	2.10	7.90
29....	12.	4.80+	7.20	12.40	4.70	7.70	9.70	4.80+	4.90	9.[illegible]	2.00	7.90
30....	12.15	5.10	7.05	12.35	4.80	7.55	9.60	4.80+	4.80	9.80	2.0[illegible]	7.80
31....	12.10	5.10	7.00	12.30	4.70	7.60	9.60	4.80+	4.80	9.70	2.05	7.65

(B.)

Record of stages of water at site of water-power—Continued.

Day of month.	1878.											
	September.						October.					
	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.
	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.
1....	9.60	4.80+	4.80	9.90	1.90	8.00	9.50	4.80+	4.70	(*)	5.70	(*)
2....	9.50	4.80+	4.70	9.70	1.90	7.80	10.40	4.80+	5.60	....	5.70	....
3....	9.40	4.80+	4.60	9.60	1.90	7.70	10.50	4.80+	5.70	....	5.70	....
4....	9.30	4.80+	4.50	9.50	1.85	7.65	10.50	4.80+	5.70	....	5.80	....
5....	9.10	4.80+	4.30	9.20	1.85	7.35	10.40	4.80+	5.60	....	5.50	....
6....	9.00	4.80+	4.20	9.15	1.85	7.30	10.60	4.80+	5.80	....	4.80	....
7....	8.70	4.80+	3.90	8.90	1.80	7.10	10.50	4.80+	5.70	....	4.10	....
8....	8.90	4.80+	4.10	9.00	1.75	7.25	10.40	4.80+	5.60	....	4.10	....
9....	9.00	4.80+	4.20	9.10	1.85	7.25	10.30	4.80+	5.50	....	4.10	....
10....	8.40	4.80+	3.60	8.60	1.80	6.80	10.30	4.80+	5.50	....	3.95	....
11....	8.40	4.80+	3.60	8.75	1.75	7.00	10.30	4.80+	5.50	....	3.95	....
12....	9.10	4.80+	3.30	9.30	1.60	7.70	10.30	4.80+	5.50	....	4.	....
13....	8.60	4.80+	3.80	8.85	1.70	7.15	10.	4.80+	5.20	....	3.95	....
14....	8.90	4.80+	4.10	(*)	1.60	(*)	10.40	4.80+	5.60	....	4.20	....
15....	9.10	4.80+	4.30	....	1.55	....	10.60	4.80+	5.80	....	4.20	....
16....	8.70	4.80+	3.90	....	1.75	....	10.50	4.80+	5.70	....	4.20	....
17...	7.40	4.80+	2.60	....	1.65	....	10.50	4.80+	5.70	....	5.35	....
18....	8.00	4.80+	3.20	....	1.50	....	10.60	4.80+	5.80	....	5.60	....
19....	7.90	4.80+	3.10	....	1.45	....	10.50	4.80+	5.70	....	4.80	....
20....	7.60	4.80+	2.80	....	1.45	....	10.40	4.80+	5.60	....	5.00	....
21....	9.10	4.80+	4.30	....	1.80	....	10.60	4.80+	5.80	....	5.10	....
22....	8.80	4.80+	4.00	....	3.15	....	10.60	4.80+	5.80	....	5.20	....
23....	8.20	4.80+	3.40	....	2.80	....	10.80	4.80+	6.00	....	5.20	....
24....	9.20	4.80+	4.40	....	2.85	....	10.90	4.80+	6.10	....	5.20	....
25....	8.80	4.80+	4.00	....	1.70	....	11.10	4.80+	6.30	....	5.25	....
26....	9.10	4.80+	4.30	....	1.85	....	11.30	4.80+	6.50	....	5.30	....
27....	9.40	4.80+	4, 60	....	3.60	....	11.	4.80+	6.20	....	5.30	....
28....	9.00	4.80+	4.20	....	2.85	....	11.20	4.80+	6.40	....	5.30	....
29....	9.10	4.80+	4.30	....	3.40	....	10.70	4.80+	5.90	....	5.20	....
30....	8.55	4.80+	3.75	....	3.40	....	11.	4.80+	6.20	....	5.25	....
31....	....	....	....	....	....	....	11.10	4.80+	6.30	....	5.40	....

* No readings could be taken at "Pool at Sylvan water dam" and at "Head of water at the United States dam" from September 14 to October 31, both inclusive; water was coffered out by putting in pen-stocks, &c.

(B.)

Record of stages of water at site of water-power—Continued.

1878.

Day of month.	November.						December.					
	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.
	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.
1....	11.	4.80+	6.20	(*)	5.25	(*)	9.85	4.80+	5.05	(*)	2.	(*)
2....	11.	4.80+	6.20	....	5.05	......	9.70	4.80+	4.90	....	1.95	......
3....	10.90	4.80+	6.10	....	4.95	......	9.60	4.80+	4.80	....	2.05	......
4....	10.70	4.80+	5.90	....	4.90	......	9.70	4.80+	4.90	....	2.00	......
5....	10.60	4.80+	5.80	....	4.75	......	9.70	4.80+	4.90	....	2.00	......
6....	10.40	4.80+	5.60	....	4.75	......	9.60	4.80+	4.80	....	1.95	......
7....	10.30	4.80+	5.50	....	4.75	......	8.70	4.80+	3.90	....	2.10	......
8....	10.10	4.80+	5.30	....	4.65	......	9.50	4.80+	4.70	....	1.95	......
9....	9.90	4.80+	5.10	....	4.55	......	8.50	4.80+	3.70	....	1.90	......
10....	9.85	4.80+	5.05	....	4.50	......	6.50	4.80+	1.70	....	1.85	......
11....	9.50	4.80+	4.70	....	4.40	......	7.80	4.80+	3.00	....	1.60	......
12....	9.25	4.80+	4.45	....	4.25	......	6.50	4.80+	1.70	....	1.65	......
13....	9.25	4.80+	4.45	....	4.25	......	6.50	4.80+	1.70	....	1.50	......
14....	9.35	4.80+	4.55	....	4.15	......	6.50	4.80+	1.70	....	1.45	......
15....	9.20	4.80+	4.40	....	4.05	......	6.40	4.80+	1.60	....	1.50	......
16....	8.70	4.80+	3.90	....	4.00	......	6.40	4.80+	1.60	....	1.45	......
17....	9.65	4.80+	4.85	....	3.95	......	6.40	4.80+	1.60	....	....	......
18....	9.25	4.80+	4.45	....	3.95	......	6.40	4.80+	1.60	....	....	......
19....	9.60	4.80+	4.80	....	3.55	......	6.20	4.80+	1.40	4.70	1.60	3.10
20....	10.	5.10	4.90	....	2.50	......	6.25	4.80+	1.45	4.95	2.45	2.50
21....	10.10	5.10	5.00	....	2.55	......	6.30	4.80+	1.50	4.35	2.65	1.70
22....	10.00	4.80+	5.20	....	2.55	......	6.40	4.80+	1.60	4.10	2.70	1.40
23....	10.10	4.80+	5.30	....	2.55	......	6.40	4.80+	1.60	7.70	3.60	4.10
24....	10.	4.80+	5.20	....	2.45	......	11.60	4.90	1.70	11.70	3.70	8.00
25....	10.	4.80+	5.20	....	2.45	......	11.75	4.90	6.85	11.60	3.50	8.10
26....	9.90	4.80+	5.10	....	2.75	......	11.65	4.90	6.75	11.60	3.60	8.00
27....	10.	4.80+	5.20	....	2.40	......	11.50	4.80+	6.70	12.	3.60	9.40
28....	10.	4.80+	5.20	....	2.25	......	11.40	4.80+	6.60	11.00	3.60	7.40
29....	9.90	4.80+	5.10	....	2.20	......	11.50	4.80+	6.70	11.00	3.30	7.70
30....	9.90	4.80+	5.10	....	2.20	......	11.10	4.80+	6.30	10.80	3.30	7.50
31....	....	....	....	....	....	......	10.90	4.80+	6.10	10.70	3.25	7.45

*No readings could be taken at "Pool at Sylvan water dam" and at "Head of water at the United States dam" from November 1 to December 18, both inclusive; water was coffered out by putting in pen-stocks, &c.

(B.)

Record of stages of water at site of water-power—Continued.

Day of month.	1879.											
	January.						February.					
	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.
	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.	6.30 a.m.
1....	10.80	5.00	5.80	10.60	3.25	7.35	10.40	5.70	4.70	10.70	3.20	7.50
2....	10.70	5.60	5.10	10.45	3.25	7.20	10.80	4.80+	6.00	10.95	3.25	7.70
3....	10.90	6.00	4.90	10.10	3.20	6.90	10.50	5.50	5.00	10.70	3.20	7.50
4....	11.10	6.00	5.10	10.00	3.25	6.75	9.90	5.50	4.40	10.10	3.15	6.95
5....	11.40	5.00	6.40	10.30	3.30	7.00	9.20	5.10	4.10	9.60	3.25	6.35
6....	11.45	6.00	5.45	10.85	3.30	7.05	9.20	5.10	4.10	9.45	3.20	6.25
7....	11.20	6.20	5.00	10.85	3.30	7.05	9.70	5.20	4.50	10.90	3.15	7.75
8....	11.25	6.20	5.05	10.25	3.25	7.00	10.40	5.40	5.00	10.60	3.15	7.45
9....	11.	6.25	4.75	10.40	3.30	7.10	11.20	4.80+	6.40	11.75	3.25	8.50
10....	10.70	6.25	4.45	10.50	3.35	7.15	10.50	5.40	5.10	10.80	3.10	7.70
11....	10.50	6.20	4.30	10.50	3.40	7.10	9.90	5.10	4.80	10.15	3.10	7.05
12....	10.60	4.80+	5.80	10.80	3.00	7.80	10.10	5.40	4.70	10.40	3.10	7.30
13....	10.20	6.25	3.95	10.55	3.30	7.25	11.	5.40	5.60	11.30	3.10	8.20
14....	9.60	6.05	2.95	9.80	3.20	6.60	11.70	5.10	6.60	12.00	3.00	9.00
15....	9.00	6.00	3.00	9.80	3.20	6.10	11.00	5.20	5.80	11.80	3.25	8.55
16....	9.00	5.80	3.20	9.25	3.20	6.05	11.35	4.80	6.55	11.60	3.15	8.45
17....	9.45	5.90	3.55	9.65	3.25	6.40	11.	5.20	5.80	11.30	3.15	8.15
18....	9.50	6.15	3.35	9.80	3.25	6.55	10.95	5.30	5.65	11.50	3.20	8.[illegible]
19....	10.30	4.80+	5.50	10.60	3.00	7.60	10.60	5.20	5.40	10.90	3.15	7.75
20....	10.30	4.80+	5.50	10.50	3.30	7.20	11.40	5.20	6.20	11.60	3.25	8.35
21....	9.90	4.80+	4.10	10.10	3.25	6.85	10.80	5.30	5.50	11.00	3.20	7.[illegible]
22....	9.55	6.15	3.40	9.80	3.25	6.55	10.20	5.20	5.00	10.30	3.05	7.25
23....	9.40	6.00	3.40	9.80	3.25	6.55	10.40	4.80+	5.60	10.40	2.80	7.[illegible]
24....	9.05	6.20	2.85	9.35	3.20	6.15	10.	5.10	4.90	10.00	3.00	7.[illegible]
25....	8.75	5.70	3.05	9.05	3.20	5.85	8.50	5.10	3.40	8.80	2.80	6.[illegible]
26....	8.90	5.70	3.20	9.25	2.80	6.45	8.50	4.90	3.60	10.20	2.85	7.85
27....	8.90	5.80	3.10	9.10	3.10	6.00	10.40	5.00	5.40	8.80	2.60	6.20
28....	8.80	5.70	3.10	9.00	3.00	6.00	10.60	5.20	5.40	10.90	3.00	7.[illegible]
29....	9.00	5.20	3.80	9.25	3.00	6.25	....	....	....	....	....	......
30....	9.40	5.70	3.70	9.70	3.10	6.60	....	....	....	....	....	......
31....	10.00	5.70	4.30	10.25	3.15	7.10	....	....	....	....	....	......

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(B.)

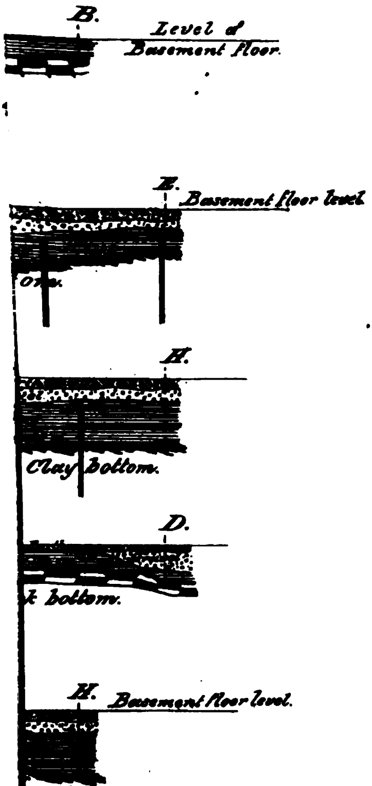
Record of stages of water at site of water-power—Continued.

Days of month.	1879.											
	March.						April.					
	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.
	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.
1....	9.30	5.20	4.10	10.60	3.00	7.60	10.20	4.80+	5.40	10.50	2.70	7.80
2....	9.30	4.80+	4.50	9.60	2.80	6.80	10.10	4.80+	5.30	10.40	2.60	7.80
3....	9.40	5.10	4.30	9.80	2.80	7.00	10.20	4.80+	5.40	10.40	2.70	7.70
4....	7.95	4.80+	3.15	8.20	2.40	5.80	10.20	4.80+	5.40	10.50	2.60	7.90
5....	6.90	4.80+	2.10	7.00	2.60	4.40	10.30	4.80+	5.50	10.60	2.70	7.90
6....	6.80	4.80+	2.00	6.50	2.80	3.70	10.40	4.80+	5.60	10.60	2.70	7.90
7....	6.90	4.80+	2.10	6.40	3.00	3.40	10.40	4.80+	5.60	10.80	2.70	8.10
8....	10.70	4.80+	5.90	11.00	3.85	7.15	10.40	4.80+	5.60	10.70	2.80	7.90
9 ...	9.80	4.80+	5.00	10.10	3.00	7.10	10.45	4.80+	5.65	10.80	2.80	8.00
10....	10.30	4.80+	5.50	10.50	3.50	7.00	10.40	4.80+	5.60	10.85	2.90	7.95
11....	10.85	4.80+	6.05	11.00	3.70	7.30	10.70	4.80+	5.90	11.00	2.95	8.05
12....	10.90	4.80+	6.10	11.20	4.05	7.15	10.80	4.80+	6.00	11.10	3.20	7.90
13....	11.10	4.80+	5.30	11.40	4.00	7.40	10.90	4.80+	6.10	11.00	3.40	7.80
14....	11.10	4.80+	5.30	11.50	4.30	7.20	10.90	4.80+	6.10	11.15	3.35	7.80
15....	10.95	5.10	5.85	11.30	4.20	7.10	10.70	4.80+	5.90	10.90	3.30	7.60
16....	11.35	4.80+	5.55	11.65	4.05	7.60	10.70	4.80+	5.90	10.90	3.30	7.60
17....	11.25	4.90	5.35	11.30	4.00	7.30	10.60	4.80+	5.80	10.80	3.20	7.60
18....	10.55	4.90	5.65	10.90	3.90	7.00	10.50	4.80+	5.70	10.70	3.10	7.60
19....	10.65	4.90	5.75	10.90	3.60	7.30	10.50	4.80+	5.70	10.70	3.00	7.70
20....	10.35	4.80+	5.55	10.60	3.20	7.40	10.40	4.80+	5.60	10.75	2.80	7.85
21....	10.20	4.80+	5.40	10.50	3.00	7.50	10.40	4.80+	5.60	10.70	2.80	7.90
22....	10.20	4.80+	5.40	10.40	3.00	7.40	10.30	4.80+	5.50	10.50	2.70	7.80
23 ...	10.30	4.80+	5.50	10.60	2.70	7.90	10.20	4.80+	5.40	10.40	2.65	7.75
24....	10.30	4.80+	5.50	10.60	3.00	7.60	10.20	4.80+	5.40	10.50	2.50	8.00
25....	10.40	4.80+	5.60	10.60	2.80	7.80	10.10	4.80+	5.30	10.30	2.60	7.70
26....	10.20	4.80+	5.40	10.50	2.70	7.80	10.10	4.80+	5.30	10.40	2.40	8.00
27....	10.00	4.80+	5.20	10.50	2.70	7.80	10.00	4.80+	5.20	10.40	2.25	8.15
28....	10.00	4.80+	5.20	10.30	2.40	7.90	10.00	4.80+	5.20	10.30	2.30	8.00
29....	10.10	4.80+	5.30	10.30	2.50	7.80	10.00	4.80+	5.20	10.35	2.20	8.15
30....	10.20	4.80+	5.40	10.55	2.50	8.05	10.00	4.80+	5.20	10.30	2.20	8.10
31....	10.20	4.80+	5.40	10.50	2.50	8.00	....	....	....	....	....	......

(B.)

Record of stages of water at site of water-power—Continued.

Day of month.	1879.											
	May.						June.					
	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.	Moline bridge.	Tail-race at Moline.	Head of water at the Moline water-power dam.	Pool at Sylvan water dam.	Tail-race below Sylvan water dam.	Head of water at the United States dam.
	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.	6.30 a. m.
1....	9.90	4.80+	5.10	10.20	2.10	8.10	14.75	7.70	7.05	15.10	7.70	7.40
2....	9.90	4.80+	5.10	10.40	2.10	8.30	14.70	7.60	7.10	14.90	7.60	7.30
3....	9.90	4.80+	5.10	10.20	2.05	8.15	14.60	7.60	7.00	14.80	7.60	7.20
4....	10.00	4.80+	5.20	10.40	2.10	8.30	14.50	7.40	7.10	4.70	7.40	7.30
5....	10.00	4.80+	5.20	10.30	2.30	8.00	14.35	7.30	7.05	4.60	7.30	7.30
6....	10.05	4.80+	5.25	10.40	2.20	8.20	14.10	7.15	6.95	4.55	7.15	7.40
7....	10.00	4.80+	5.20	10.40	2.15	8.25	13.90	6.80	7.10	4.15	6.80	7.35
8....	10.10	4.80+	5.30	10.30	2.15	8.15	13.70	6.50	7.20	4.35	6.50	7.85
9....	10.00	4.80+	5.20	10.20	2.20	8.00	13.50	6.30	7.20	3.80	6.30	7.50
10....	9.90	4.80+	5.10	10.20	2.15	8.05	13.40	6.20	7.20	3.60	6.20	7.40
11....	10.00	4.80+	5.20	10.30	2.10	8.20	13.30	6.15	7.15	13.60	6.15	7.45
12....	9.90	4.80+	5.10	10.25	2.05	8.20	13.20	6.10	7.10	13.70	6.10	7.60
13....	9.95	4.80+	5.15	10.40	2.00	8.40	13.00	5.75	7.25	13.40	5.75	7.65
14....	10.00	4.80+	5.20	10.30	2.20	8.10	12.70	5.55	7.15	13.00	5.55	7.45
15....	10.10	4.80+	5.30	10.40	2.20	8.20	12.60	5.50	7.10	12.85	5.50	7.35
16....	10.10	4.80+	5.30	10.50	2.25	8.25	12.60	5.30	7.30	12.80	5.30	7.50
17....	10.15	4.80+	5.35	10.50	2.30	8.20	12.35	5.10	7.25	12.80	5.10	7.70
18....	10.30	4.80+	5.56	10.70	2.35	8.35	12.20	4.80	7.40	12.60	4.80	7.80
19....	10.40	4.80+	5.60	10.70	2.50	8.20	11.90	4.50	6.40	12.30	4.50	7.80
20....	10.70	4.80+	5.90	10.90	2.90	8.00	11.75	4.45	7.30	12.00	4.45	7.55
21....	11.10	4.80+	5.30	11.50	3.20	8.30	11.60	4.20	7.40	11.90	4.20	7.70
22....	11.50	4.80+	5.70	11.90	3.80	8.10	11.55	4.15	7.40	11.80	4.15	6.65
23....	11.90	4.80+	5.10	12.20	4.10	8.10	11.40	4.00	7.40	11.65	4.00	7.65
24....	12.30	4.95	7.85	12.60	4.60	8.00	11.20	3.80	7.40	11.55	3.80	7.75
25....	12.75	5.10	7.65	13.00	5.10	7.90	11.20	3.75	7.45	11.50	3.75	7.75
26....	13.10	5.70	7.40	13.30	5.50	7.80	11.05	3.70	7.35	11.50	3.70	7.80
27....	13.45	6.00	7.45	13.70	6.00	7.70	11.10	3.80	7.30	11.55	3.80	7.75
28....	13.80	6.40	7.40	14.00	6.50	7.50	11.30	3.70	7.60	11.60	3.70	7.90
29....	14.00	6.80	7.20	14.20	6.90	7.30	11.30	3.75	7.55	11.50	3.75	7.75
30....	14.20	7.00	7.20	14.50	7.10	7.40	11.30	3.80	7.50	11.55	3.80	7.75
31....	14.90	7.50	7.40	15.00	7.70	7.30	....	....	....	....	....	......



tion

x K.—Report of Chief of Ordnance, 1879.


D.
E.
clay

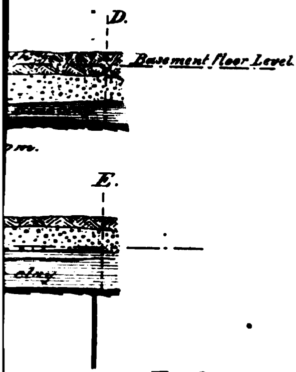
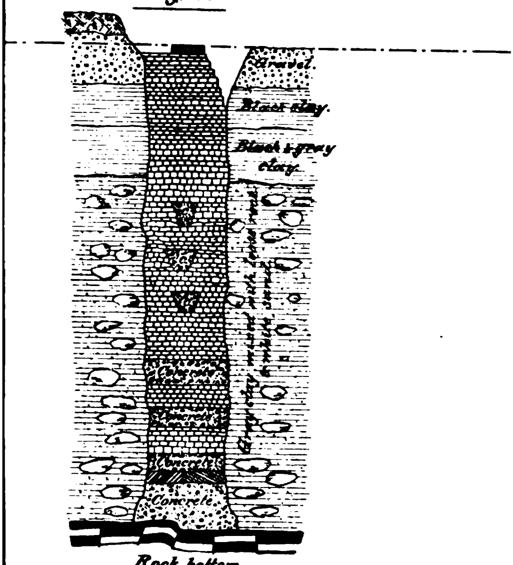
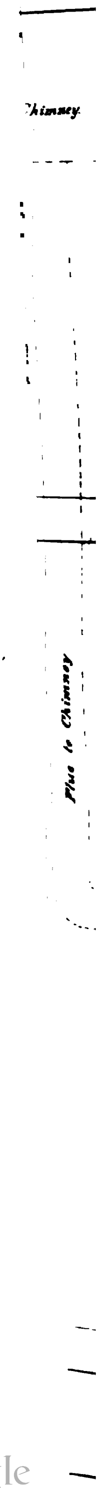


Fig. 3.



Cross Section at Z. Z.


Chimney
Flue to Chimney

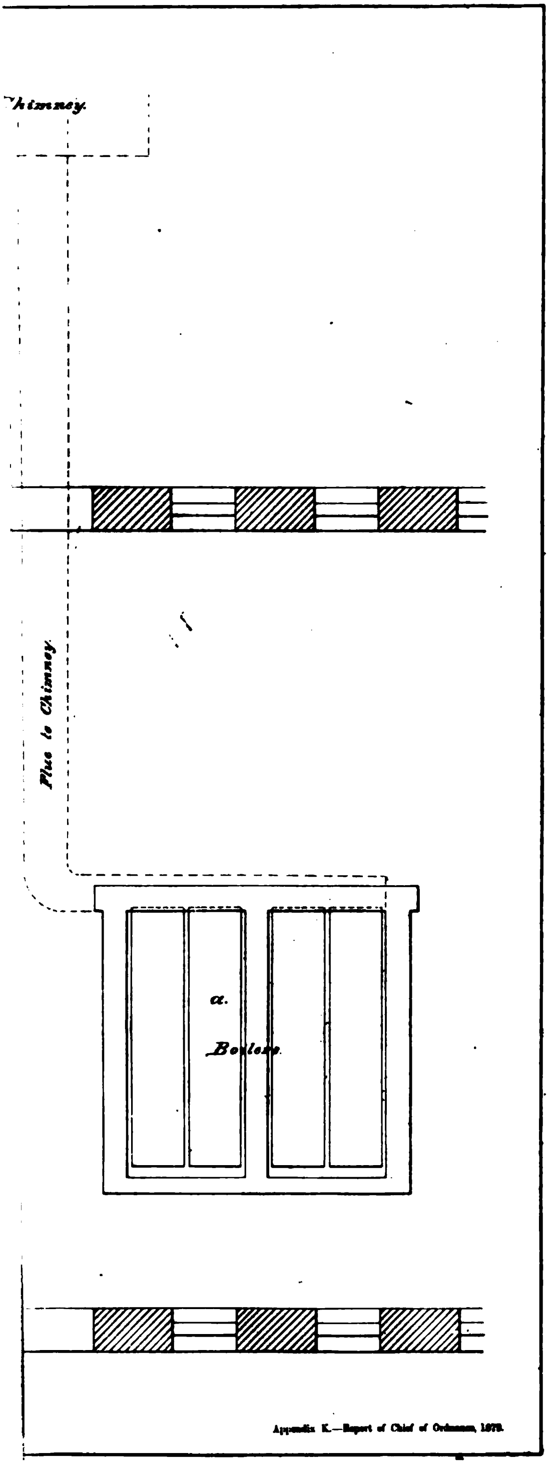
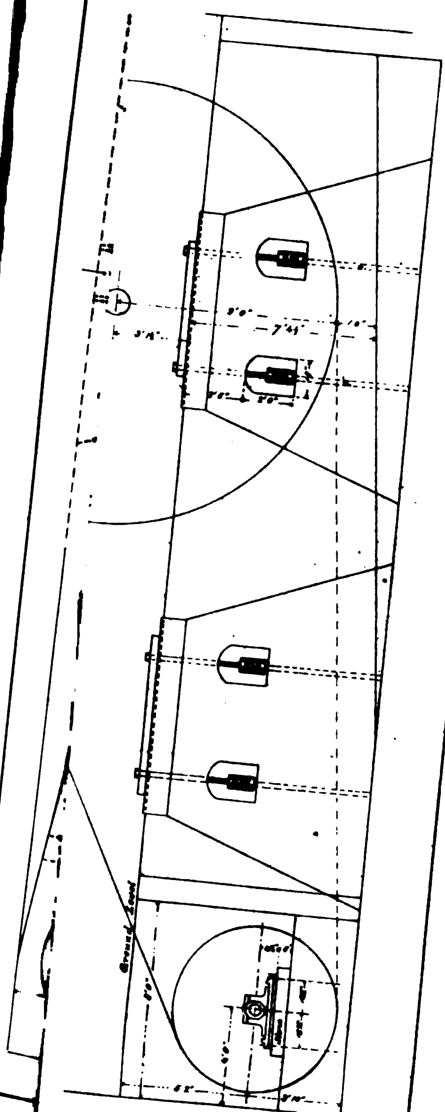
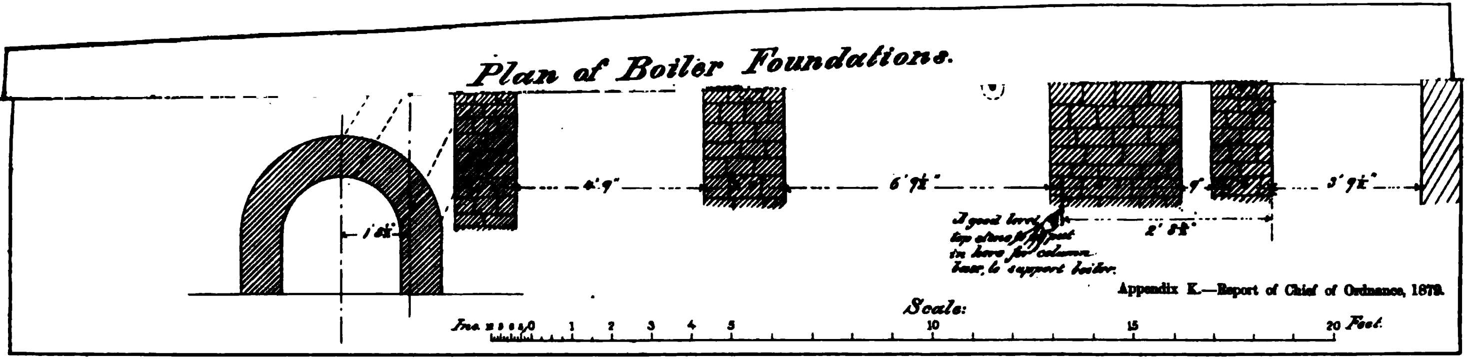

Chimney.
Flue to Chimney.
a.
Boilers.

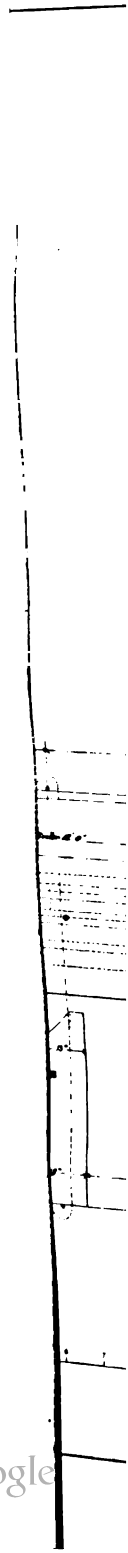
PLATE IV

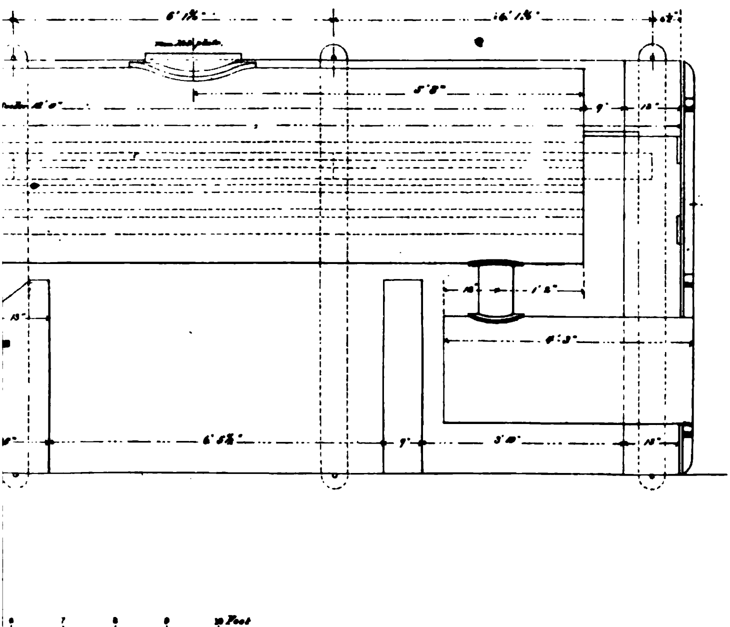


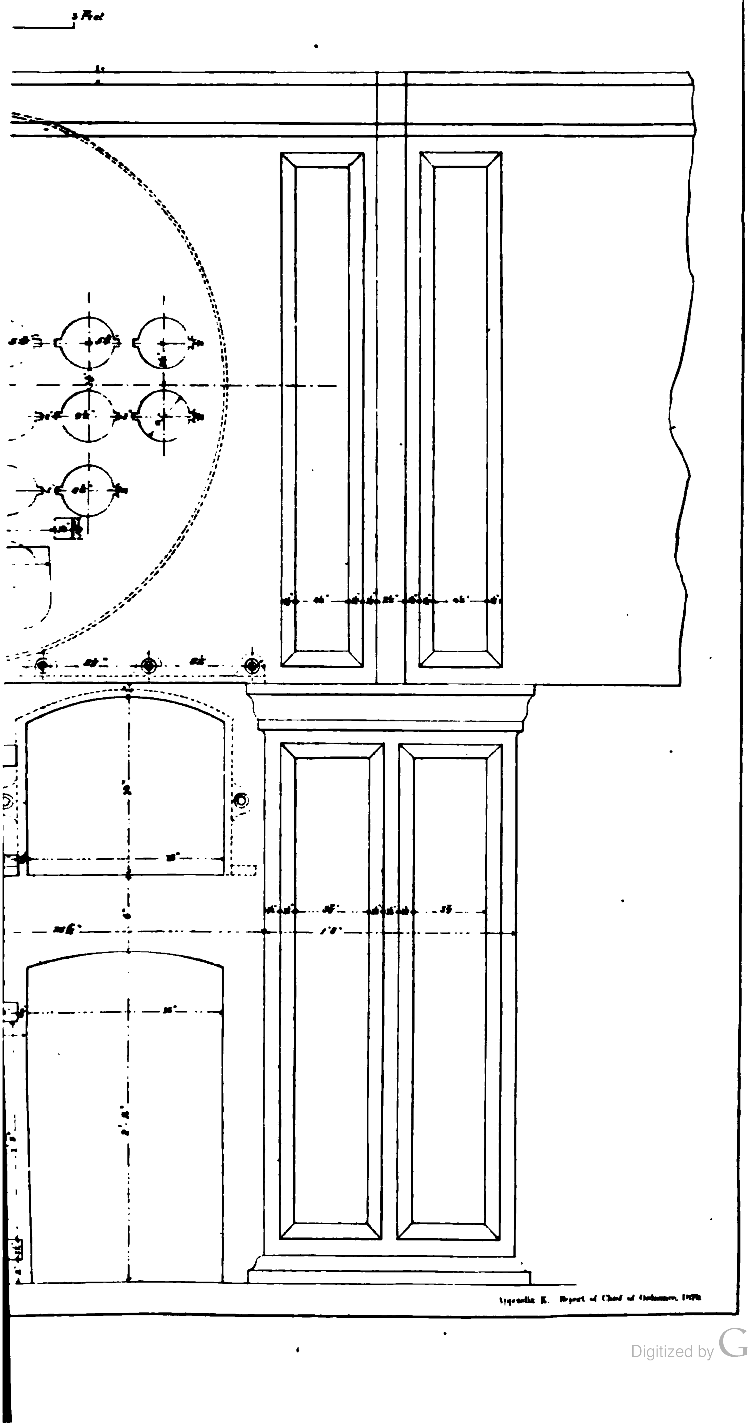
Appendix K. Report of Chief of Ordnance, [illegible]

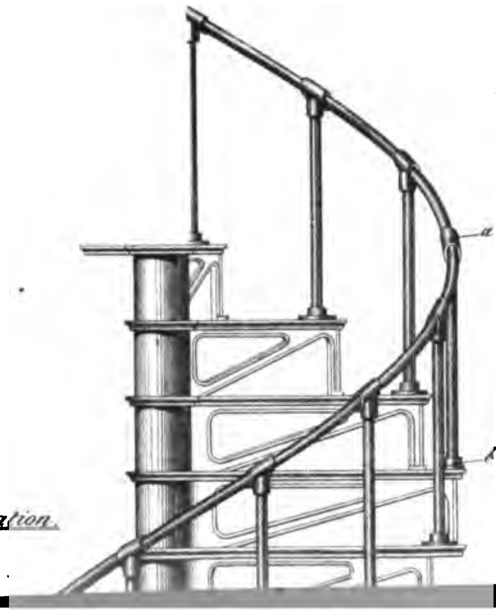


Appendix K.—Report of Chief of Ordnance, 1879.









Side Elevation.

Cast Iron Winding Stairway.

for

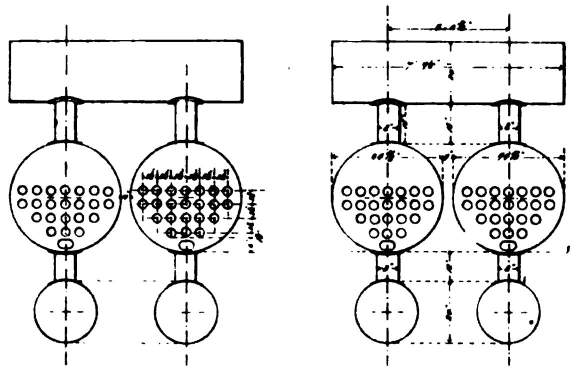
Shop F.

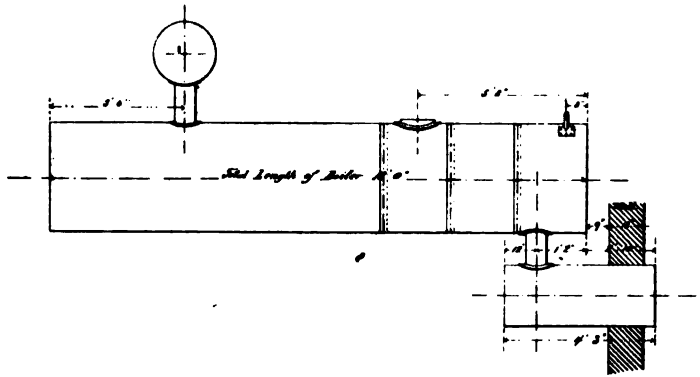
Rock Island Arsenal.

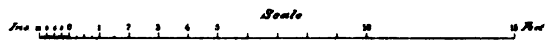
Designed by Col. D. W. Flagler.

Legend.

Weight of Post (7 ft long)	190	lbs.
" " Riser	30	"
" " Tread	47	"
" " Splice	21	"
" " Splice "a" for Hand Rail	14	"
" " Cast iron foot "b" for Banisters	12	"







Boilers for Shop F. Rock Island Arsenal.

April 8th 1878.

Four (4) Boilers, inside diam. of Shell 44 in. Length 18'-0". Shell to be made of 5/16" iron
Heads to be made of ½" iron. Each Boiler to have 22 four inch flues, flues to be
expanded into heads. Each Boiler to have one mud drum, to be made of ¼ in. iron, to be
24 in. in diam. & four ft 3 in. (4'3") long, and to be connected to Boilers by wrought iron
connections 8 in. in diameter & 12" long. — Each pair of Boilers to have one Steam drum
24 in. in diameter & 7'-9½ in. long, to be made of ¼ in. iron, and to be connected to Boilers
by wrought iron connections, 8" in diameter & 16" long.
Each Boiler to have man hole plate, cap & dog. Position of steam drums, Mud drums,
man hole and hanger eyes, as shown in drawing.

APPENDIX L.

PROGRESS REPORT ON THE ARTESIAN WELL AT BENICIA ARSENAL DURING THE FISCAL YEAR ENDED JUNE 30, 1879, LIEUT. COL. J. McALLISTER, ORDNANCE DEPARTMENT, COMMANDING.

GENERAL: I have the honor to report that the work of sinking an artesian well at this arsenal has been prosecuted during the past year as far as practicable, considering the appropriation made by the first session of the Forty-fifth Congress, and the fact that no appropriation was made for this undertaking by the second session of that Congress, nor by the extra session of the new Congress.

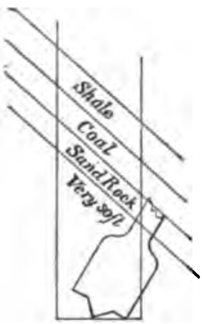
The present report is the sixth on this subject, and the date of the last one, August 14, 1877, shows that two years have elapsed since I wrote you in reference to this matter, and the question whether the people on this coast, failing to secure surface water, can procure by boring, good artesian water, is still unanswered. This is a matter of great moment to all the residents, manufacturers, rancheros, and even to the land speculators and financiers who reside here or are interested in the prosperity of the States west of the Rocky Mountains. No person on this coast has yet obtained artesian water, nor has any individual or company bored to the depth which has been reached by the well at this arsenal.

An estimate of $6,705 was asked for in July, 1876, but Congress only appropriated $5,000 for continuing this work during the fiscal year ending June 30, 1877. The above estimate was based on the experience gained in prosecuting this undertaking during former years, but as the well deepened the expenses to be incurred increased with a ratio which was not fully appreciated at the time the estimate was made, and the action of Congress in decreasing the sum estimated for by the amount of $1,705 of course added to our embarrassments. The work was discontinued at the end of April, 1877, for want of funds, leaving the well 1,407 feet deep. If money could have been obtained at that time to continue boring, the success of sinking an artesian well at this post deep enough to obtain pure water would most probably have been *un fait accompli*.

A work of this character should be continuous, if it is to be conducted with any regard to economy, especially while we are using the same diameter of pipe to line the walls of the well. The time employed at the well should constantly be increased until the work is prosecuted day and night; for, as the length of pipe is increased the danger of its becoming immovable in the well is also increased, and it is only by keeping it moving that this can be avoided. The 7-inch pipe as it is forced into the well, for every inch of depth presents a surface of 22 square inches to adhere to the walls of the well, and the friction between the outside surface of the pipe and the walls of the well, increases proportionally. While work is continued day and night no difficulty in moving the pipe is experienced provided the well wall is true, but when a year is allowed to elapse between the time of stopping and resuming work, a silicate incrusts the outside of the pipe and glues it to the walls of the well, so that it has to be all taken up, as it cannot be moved downwards, and to effect this portions of it have to be wrenched from the sides of the well.

As so much time has elapsed since my last report was rendered, a summary of the condition in which the well was left when work on it was discontinued in April, 1877, will not be out of place.

The well had been bored to a depth of 1,407 feet 10 inches, and a drill had been left at the bottom broken off from the rods. The 11-inch diameter pipe reached to a depth of 200 feet from the surface of the ground, the 9-inch pipe to a distance of 557 feet, the 8-inch pipe to a depth of 959 feet, and the 7-inch pipe to 1,372 feet 9 inches, or to within 53 feet 1 inch of the bottom of the well hole.



The supply of water afforded by the well in the condition when work ceased was plentiful; a deep-well pump was placed in the well 200 feet below the surface of the ground, and although the water was pumped out for sixty hours, yet this only lowered the water slightly and the supply continued abundant. This water came from two sources—the one 960 feet from the surface where the 8-inch pipe terminates, and the second from the bottom of the well.

It was determined to derive some benefit from this water and to make arrangements so that it could be used in case of fire, for the boiler in the shops, and for irrigation. The best method of effecting this was to pump the water directly from the well into the reservoir, from which it could be distributed to all parts of the post. In this case the height through which the water was to be forced might be 300 feet, as follows: The difference of level between well and reservoir was 180 feet, and the water might be lowered in well, by continuous pumping eight hours a day, about 120 feet from the surface. To pump the water through this height would have subjected the piston of pump and the pipes to a great strain, as we must include in our estimate the friction of the water on the inner surface of the pipe, which would have to be overcome, as well as the actual weight of water to be raised. It was decided to pump this water into another well which furnished us with about 1,500 gallons of hard, slaty water every day during the dry season, and from thence to force it up into the reservoir on the hill by means of a Knowles steam-pump.

The analysis of the water obtained from the well resulted as follows:

After standing some time a dark precipitate formed from a wine-gallon of the water, and, having been filtered, was found to weigh 13.063 grains. It was composed of the following: Silica, 5.890 grains; *organic matter*, 4.374 grains, and oxide of iron, 2.799 grains.

A qualitative analysis showed the presence of the following substances: Soda, iron, organic matter, ammonia, chlorine, carbonic acid free and combined; also, traces of sulphuric and boracic acids. The quantity of carbonic acid free and combined was found to be 9.155 grains in one wine-gallon of water. This water proved to be alkaline and impure from the presence of *organic matter*. It is very soft, and free from lime and magnesia; but the presence of organic matter rendered the water unfit for food. This water was used, mixed with the hard water of the small well, during the dry season, for irrigation and for the animals. It did not seem to disagree with the latter. Some violets which were irrigated faded and died, but it seemed to agree with the grasses and trees.

We were astonished at finding organic matter in water rising from a 1,407-foot level, and could only realize that this analysis was correct when we remembered that coal was found near this stream of water.

Notice was received at this arsenal on July 16, 1878, that another appropriation had been made for prosecuting work on the artesian well. I made a complete examination immediately of all the tools and apparatus on hand for this work, and the opinions which were expressed in my last report, *i. e.*, that the engine and boiler could not perform the required work any longer, was verified. It was also resolved to remodel some of the tools and to duplicate others. The necessity for doing this last was explained in my previous report. It will be remembered that in pushing down the pipe during the year 1877 the force required to effect it was proportional to the upward spring of the pipe when relieved from the pressure. This upward spring was sometimes as great as 4 inches, which was considered as proving that a pressure of over 20 tons had been used before the pipe commenced descending into the well. Such a force was very injurious to the rivets which held the pipe together, and if they failed to sustain it the pipe would certainly telescope, and its interior diameter be diminished so that the tools could not pass freely to the bottom of the well. This fact and the weight of the sheet-iron pipe already in the well, which was 15,000 pounds, determined us to use no more of it, but on top of this double sheet-iron pipe to fasten heavy wrought-iron artesian-well tubing. This we ordered from Philadelphia, and Lieutenant-Colonel Whittemore, who commanded at Frankford Arsenal, had the kindness to inspect it for us. This inspection had to be made very carefully, as the tubing must be perfect as regards straightness, and there were very small limits to be allowed in regard to the interior and exterior diameters.

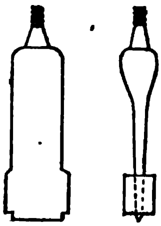
This length of tubing, 700 feet, would enable the well to be sunk and piped to a depth of 2,072 feet, which was considered as a depth sufficient to demonstrate the success or failure of the effort to obtain a flowing well of large capacity. It will be remembered that a flowing well of some 1,000 gallons per day has already been obtained from the 960-foot level, the water from this stream rising in the pipe as far as the latter reached above the ground, *i. e.*, two feet, and flowing over its edges.

Of course in all the deliberations which resulted in the procurement of new machinery and the fabrication of new tools an appropriation for this work by Congress for the succeeding year was a conspicuous element. Representations had been made in the last report which proved conclusively the great loss which the government had experienced in allowing this work to be discontinued for a year, and on the principle that "a burnt child dreads the fire," it was confidently expected that money would be appropriated for this work, and all the improvements in machinery and tools were made on that supposition.

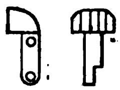
The new boiler was 20 feet long, 42 inches diameter, with two flues, each 16 inches diameter; steam-drum 48 inches long, 30 inches diameter, with mud-drum and safety-valve. The engine employed was the portable one which had been on hand for some years at this arsenal, and was capable of developing twelve horse-power.

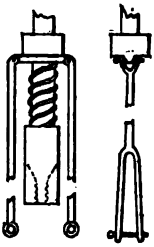
A new steam-cylinder for working the end of the lever opposite the one to which the boring-rods were attached had to be made and fitted; it was a single-action cylinder, the feed automatic, 9 inches interior diameter and 4 feet high. Four new drills were made, and the form of these was improved. It had been observed that in all cases in which the drills were broken in the well the line of fracture or weakness was exactly where the screw joined the drill, or where the coupling of the side cutter-tool seemed to rest on the drill when they were screwed together.

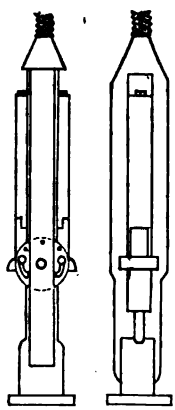
The new drills were made with cones between the screw and body of drill, which fit into inverted cones in the couplings on the tools above. The side strains are borne partially by these cones and not entirely, as heretofore, by the male and female screws of these tools.



Two side-cutter tools were fabricated of a new device which rendered them more serviceable. This tool consists of a frame of wrought iron to hold two side-cutters, one on each side, and is screwed on to the rods above the drill. The side-cutters are made of steel; they revolve around a pin in the center of the tool, and have serrated cutting surfaces. The frame for this tool is of wrought iron, 2 inches thick; the cross-section is that of a cross; the side-cutters work between two steel circular plates, to which they are fastened by a steel pin which passes through the centers of these plates and through the holes in the shanks of the side-cutters. Around the pin, the latter move through an arc of 45°, so that they can be kept closed when passing down the pipe, and, also, that they will close themselves in passing up the pipe by being pulled up through it. There are two slots in each plate which, when the tool is assembled, are directly opposite similar slots in the other plate; these slots would be portions of the same ring, if it was cut around the plate. A steel pin passes through each slot in the plate through a hole in one of the side-cutters near its head, and out through the slot in the opposite plate. This pin projects beyond both plates, and has a screw-thread on one extremity, with a nut to fit the screw. These side-cutters are kept open by a spiral spring which works up and down around an iron bar belonging to a tool just above side-cutter frame. This spring works between a fixed collar at the bottom of the bar and a sliding collar above it. To the latter are attached two arms and from them hang two forked rods, one on each side; the prongs of these forks have round holes through their extremities, and they pass down, one on the outside of one circular plate, and the other on the outside of the other circular plate. The pins last mentioned, after passing through the holes in side-cutters and the slots in circular plates, pass through the holes in the prongs of the forks; and the whole system is held together by the nuts screwed on to the end of the pins. When the side-cutters are open to the full extent, the backs of each of them rest upon a shoulder between the two circular plates; so that there is no yielding upward as the tool falls to the bottom of the well in boring. To use this tool, we take hold of the forked rods and pull them down against the spring until the heads of the side-cutters are as low as they can be got, then place wooden pegs between side-cutters and shoulders; these will hold the former in place until the tool is lowered through the pipe. When boring is commenced, the first or second stroke will loosen the pins, which will then float to the top of the water in the well, and prove to the workman that the side-cutters are working. As soon as the pins escape, the spring will cause the side-cutters to open back and upwards until they rest against the shoulders; then they will commence to do their work.





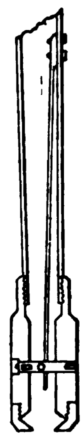


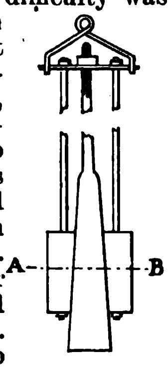
Two free-falling tools had to be repaired; they work automatically, and were fully described in my report dated July 19, 1873.

It was found necessary to make a new pump of heavier material than the last, but no change was made in its construction.

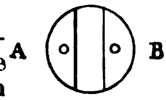
The old pipe had to be removed from the well, and, as it could not be stirred in its present state, it was necessary to cut it into sections; in order to effect this we prepared a tool which would cut through the sides of the pipe at any distance from the top of it.

We took the tool described in my last report, which was made for removing broken wooden poles from the well, and adapted it to this work by removing the pawls from the hollow iron cylinder. A steel bar 1¾″ by 1½″ was placed across the above-mentioned cylinder, working horizontally in two rectangular slots; its center was pierced by a hole, through which a steel pin was passed, which projected on each side of the bar; against these projections the prongs of a steel forked-shaped spring impinged and pressed the bar always in the direction of the end in which the cutter was fastened. The cutter was rounded and had serrated edges, and was fastened on the bar, which had a sliding motion. The extent of this horizontal movement was controlled by two pins passing through sides of cylinder and through longitudinal slots in bar; the latter were one inch long. To use this tool we press in the cutter while inserting the tool in the pipe, and as the latter is lowered the point of the cutter will make a mark down the inside of the pipe, but one which will not injure it. When the tool has reached the place at which the pipe is to be cut through we commence to turn it around, and, as the outer line of the teeth of the cutter is a circle, the deeper the incision in the pipe the greater number of teeth will come in contact with the substance of the pipe. If the first attempt is unsuccessful and the cutter is dulled before the pipe is cut through, compelling us to withdraw the tool in order to sharpen the cutter, it is found very difficult to resume the work at the same place, owing to the expansion of the system of rods due to the length suspended and the increased temperature at great depths. This difficulty was overcome by placing an iron plate 8 inches diameter on the system of rods, with a hole in it so that the rods might turn freely, the upward movement of the plate being controlled by a small collar fastened to the rods by a set-screw, the bottom of this plate to be at a distance above the cutter which should be equal to the length of pipe we wish to remove at any one time. Then, as the cutter reaches its position, the plate will catch on top of the 7-inch pipe and the small collar will hold the rods, so that the cutter can only have a horizontal motion around the axis of the rods. It can be readily seen that by keeping this plate and collar on the rods that the same place in the pipe will be reached each time that it is lowered after sharpening the cutter. After the pipe was cut through it was found impossible to raise the tool until the cutter was broken off, but there was no difficulty in doing this.



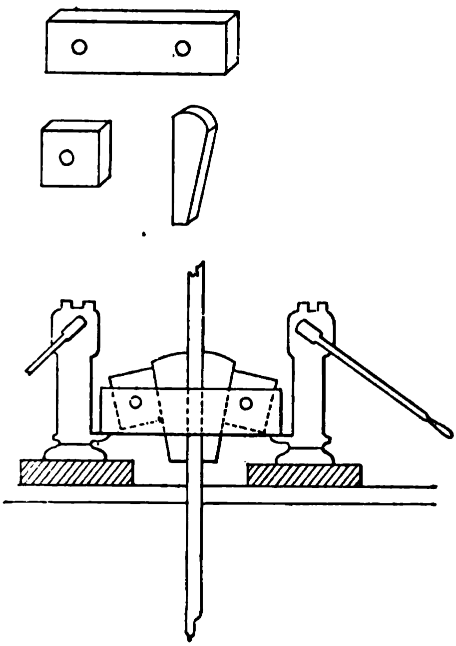


The next tool fabricated was one to rivet together sections of pipe 30 feet long, it being anticipated that we would insert this 7-inch pipe into the well after it had been repaired, in lengths of 30 feet at least, until it reached below the 8-inch pipe. This tool is composed of two cast-iron solid segments of cylin-



ders attached to the lower extremities of two rods with a wedge, which has a vertical motion, suspended between them, the edge of the latter being upward. The outer surfaces of the two segments and the ends of the wedge, when it is pulled up, form a solid cylinder the diameter of which varies with the height of the wedge. The *modus operandi* is to lower the pipe into the well and then to hoist a 30-foot section up into the well-tower; the bottom of the latter is then driven into the top of the former by blows on top of the new section of pipe. The holes for the rivets were then drilled through both pipes and soft screws inserted; the riveting tool is then lowered so that the segments of the cylinders cover the joint of the pipes which are to be fastened together; the wedge is then raised by turning the nut on the top of the vertical screw which holds it in suspension. Raising the wedge presses the segments against the inside of the pipe and rivets; then the latter are hammered from the outside, and the nut being reversed the screw and wedge attached to it are lowered, the segments approach each other and the pipe descends into the well. As soon as the pipe is let down into the well sufficiently the riveting tool is raised out of it.

We found that the operation of withdrawing portions of pipe from the well-bore required a power far exceeding the strength of our engine and steel-wire rope. The power exerted to do this amounted in some instances to more than 30 tons. In order to apply the hydraulic pumps to the rods we made a system of clamps and wedges, and, after securing a good hold on the rods with these, we placed the hydraulic pumps under the edges of the former. The clamp consists of four steel plates, the smaller ones were placed between the two larger, and each was pierced with a 1-inch hole. The plates were assembled around the rods and were held in position by two bolts. Two steel wedges were driven in on each side of the rods between them and the edges of the smaller steel plates, then the pumps were applied to the bottom edges of the larger plates, one on each side, and the greater the pressure employed the more firmly did the wedges grasp the rods. In extricating tools which had become fast in the well, in some instances two of these clamps were used, one above the other, and at right angles to each other, so that four pumps could be employed simultaneously.



Besides manufacturing tools, some work had to be performed on well tower and machinery; all of the latter, save lever and the steam-cylinder which worked it, were removed to the south of the well, so that the machinery should no longer feel the constant jar created by the lever in boring. The system of rods, weighing over 6,000 pounds, alternately raised and lowered 20 inches, and this twenty-five times per minute, caused a consider ab

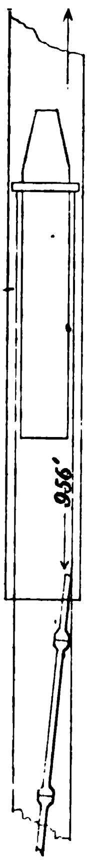
which was communicated to the frame of the lever, and by it to the floor timbers and to all the machinery supported by them. This tremor, which was felt by everything on the same foundation as lever, proved injurious to pipe and rod connections, &c., therefore a shed-room was built on south side of well on a separate foundation from that on which old machinery stood, large enough for steam-engine, boiler, hoisting-machine, reel for pump-rope, &c. The shaking, which is unavoidable in working the lever with its rods and weight, is not felt in this new room.

Again, we had been very much cramped for room during the last year that we had worked. Fifty rods and many tools were suspended around the well-hole, and there was hardly room enough to work. We were compelled after using certain tools and employing many rods to place them outside of the tower until they were wanted. Carrying 30-foot rods out and in the tower occupied much time, and proved very inconvenient; besides, they did not maintain their straightness when lying on the ground or skids as well as if they were suspended. It was, therefore, determined to raise the well-tower another story. After this was done a new rack and frame was made and placed in upper part of tower. From this the poles and tools were suspended, and there was abundant space below them to allow the men to work.

The flat wire-rope, sheave, and metal boxes of hoisting apparatus were worn out and had all to be replaced. The wire pump-rope, already weak in places, was considered unserviceable, notwithstanding great care had been taken to preserve it during the two years that it was allowed to be idle. Finally, after having to expend most of the appropriation on tools and machinery, the work itself was really commenced. We first cleared the well of the deep-well pump which had been used to raise the water and to force it into the other well as described above. When this was done a wooden block was lowered to feel for the top of the 7-inch pipe, which was found 303 feet below the surface of the ground. A cylinder gauge made of wood was lowered 540 feet to ascertain if the pipe was free to that distance, so that arrangements might be made to cut off 200 feet of it. As everything was clear, the cutting-tool was placed in well, but could not descend beyond a depth of 330 feet. It had entered the 7-inch pipe 27 feet, but could be forced down no further. After withdrawing it and attempting several times to remove the obstruction by using different tools, and our efforts proving unsuccessful, it was determined to use the pipe-extractor, which was described on page 50, Report of the Chief of Ordnance for 1876. We finally extricated from the well 46 feet 8 inches of pipe. This was accomplished by using the hydraulic pumps and breaking the rivets which held it together. Our next attempt was to cut the pipe at a distance of 560 feet from the top of it. The cutter became so dull that the tool had to be raised and a new one substituted for it twice before we effected our object. The pipe-extractor when employed brought up 210 feet of pipe, but we had to use the wooden clamps on the outside of the pipe and two hydraulic pumps before we could start it upward. Several successful efforts were then made, during which no serious accident occurred, to remove sections of pipe, and 680 feet were removed from the well. If one tool failed us we tried another. In some instances the pipe was cut through in two trials, but it generally required more. The pipe-extractor threatened to give us trouble, for the wooden block belonging to it would swell to such an extent by the absorption of water that after raising the pipe from the well it was found necessary to cut away the pipe in order to extricate it.

After accomplishing the above, preparations were made to cut the

pipe through 940 feet from the surface of the ground, or 19 feet above the bottom of the 8-inch pipe. Several cutters were broken in trying to accomplish this; and when we thought it was done, the pipe-extractor was used, and, instead of bringing up 940 feet, it only extricated 22 feet of pipe, the rivets at the end of this section having broken, which accounted for the pipe yielding at this particular place. Another hold was obtained on the pipe, but nothing was accomplished, and we desisted in our attempts to raise this long section, and commenced to extract shorter lengths. By working alternately with cutting-tool and pipe-extractor, and after many failures, we found that we had removed 922 feet 8 inches of the pipe; this left the top of the 7-inch pipe 26 feet 5 inches within the 8-inch pipe.



We were now approaching difficulties which had been anticipated, but which could not be avoided. Our ingenuity failed to suggest any adequate precautions to be taken which would insure an easy-bought success. As soon as the top of the 7-inch pipe no longer rested within the 8-inch pipe, the walls of the well-bore between the top of one pipe and bottom of the other would be unsupported, and would commence to cave. The strata, composed as it was of shale, slate, and rotten sand-rock, would crumble down into well-hole on top of the 7-inch pipe, and bury it. In order to try to avoid such a catastrophe, which we feared would occur, it was determined to make a desperate effort to raise the whole of the pipe remaining in the well, 450 feet, at one trial. A hold on this pipe was obtained near the bottom of it, and we used the hydraulic pumps, but the pipe was a fixture in the well; that is, the above means, which were all that we had on hand, proved inadequate to move it. The pressure of the pumps was applied with judgment, being increased very gradually until the iron rods broke at a distance of 956 feet from the floor of the well-tower. This distance was a few feet less than the length of the 8-inch pipe, therefore the top of the broken system of rods was within the 8-inch pipe. The rods did not break at a coupling, but in the middle of a short rod, 10 feet long, and there was no imperfection of metal to account for the breakage. The rod was 1 inch square, and its rupture proved that the four hydraulic pumps had been used to their full capacity, and that a pressure of nearly 60,000 pounds must have been employed without moving or breaking the pipe. After this accident the position of pipes and tools were as follows: The 8-inch pipe overlapped the 7-inch pipe 27 feet 4 inches, the top of the poles being fortunately in that portion of the latter which was within the former, and the gravel-box of pipe extractor, made of sheet-iron, was resting on top of 7-inch pipe. The rods and box had to be withdrawn before anything else could be accomplished towards removing any more pipe. The kit-extractor was lowered, and, by the impression taken, it was ascertained that the hole in conical top of gravel-box was in the axis of the well-hole. An attempt to extract this was made with a hook on a swivel at the end of pump-rope, as this could be lowered in a few minutes, while the system of rods would take more than one hour to reach this distance into the well. A hold on the top was secured, but the rope parted at an old splice, leaving an additional obstruction in the well in the shape of some hundred feet of wire-rope. The rope and its appurtenances, after several trials, were withdrawn from the well. After re-splicing the wire rope it was lowered, with

a point of iron at its extremity, attached to which were four iron springs. This tool passed through the hole in top of gravel-box, and when it was drawn up the springs caught the sides of box and brought it out of the well. As the 7-inch pipe projects more than 20 feet above the upper end of the bottom rods in well, there was room above the latter to permit us to use another pipe-extractor in this pipe, and to try to remove some of it, and thus relieve the rods in well of a portion of the weight which served to break them in our endeavor to raise the whole of it at one trial. We were successful, and raised 78 feet 4 inches. On examination it was ascertained that the pipe was not cut through at the depth of 940 feet, the point at which the cutting tool had been working. This was owing to the fact that the cross-section of the pipe was not a circle at this place, but rather an ellipse, two of the opposite sides having been pressed in towards the center. The cutter had perforated all the inner sheet and the portions of the outer one near the extremities of its smaller diameter, but the outer sheet at the ends of the larger diameter was intact. By raising this length of pipe we had relieved the rods of 861 pounds actual weight, but when we consider that the outer surface of this portion of pipe was over 1,700 square feet, and the power of adhesion to the walls of the well-bore was proportional to it, we can realize that the pressure exerted by the actual weight was a very small component of the strain that the rods had to sustain, and that in removing this length of pipe the rods had been relieved of a great portion of the task which had been required of them.

The above was the first operation towards rectifying the effects of this accident; but the rods were still in the well, and there was now a portion of the walls of the well 51 feet, extending from bottom of eight-inch to top of seven-inch pipe, unprotected and liable to cave.

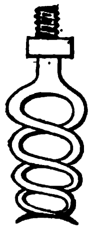
No time was lost in trying to get a firm hold of upper extremity of rods in well. Several tools were made of different patterns, but all proved ineffectual, our hold on top of rods yielding before a pressure adequate to raise them could be applied. Our next attempt was to unscrew a portion of the rods and to raise these from the well; about 40 feet above the gravel and block there was a loose joint, and if a sufficient hold could be obtained of the top of the rods, we might unscrew the upper ones. Several attempts were made to effect this, but our hold on the rods slipped, or the leverage of 956 feet from top of rods to the place of applying the power with the elasticity of the rods prevented our unscrewing them at the loose joint. Our exertions to take hold of the rods and the constant blows the top of them received from the tools in trying to effect this pushed the whole system in the well down until the block was worked below the pipe, when the gravel escaped out into the well-hole and the claw tool obtaining a hold on the coupling just below the rupture brought rods and block to surface very unexpectedly. This method of freeing the well from this tool when it was found impossible to raise it was one of the considerations which induced us to use it, but it was not tried in this instance, as it was supposed that the whole well below the 7-inch pipe was filled with loose rock and earth, and that there was no room for either block or gravel.

We next raised out of the well 30 feet more of pipe, leaving a distance of 81 feet of bore of which the walls were not protected. Our prospects were now encouraging, as we experienced very little difficulty in achieving this last result. The well was left in this condition on stopping work at night, and it was resumed with sanguine anticipation on the following day. These were soon exchanged for gloomy fore-

bodings, for, on lowering the pipe extractor, it was ascertained that during the night the walls of the well had caved in on top of pipe at a

distance from the surface of the ground of 1,030 feet. This *débris* was bored through with an auger, and, after penetrating it and reaching the pipe, the tool descended freely in the latter. It was found that the pipe extractor could not enter the pipe, as there was some obstacle on top of it which the auger could pass by, but which was large enough to obstruct the passage of this tool, while the same obstacle kept the *débris* above from filling up the pipe.

In raising the auger on one occasion the workman was certain that he had caught hold of this piece of rock or sheet-iron and was lifting it out, but when the auger was within 210 feet of the surface a sudden jar of the rods convinced him that it had escaped and fallen back into the well. On lowering the tools it was ascertained that they would not enter the pipe, and the piece of rock or hard substance was felt on top of it. A double worm was then tried, several attempts were made, and



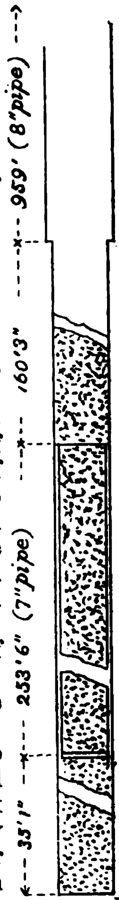
in some cases this obstacle was nearly raised to the top, but fell back into the well. It was then determined to break it up and extract it in fragments. A solid inverted cone was screwed on to the rods and slide, the whole system was raised and allowed to fall, but this did not break it up so that we could remove it. The idea of extricating ourselves from this difficulty in this manner was finally abandoned, and we commenced to use a sharp-pointed drill and to bore in the usual way, but without side cutters, using the pump alternately with the drill. By continuous employment of these tools we reached the top of the pipe and entered it to a depth of 100 feet, when we found it filled up to that height with caved rock and earth. This length of pipe afforded us another opportunity of using the pipe extractor, and a hold on the former was obtained at a distance of 70 feet below its top. The clamps, wedges, and hydraulic pumps were applied, and the pressure was increased very gradually, the full strain of the four pumps being left on during the night. The following morning the influence of the pumps began to tell on the system of rods, and they yielded gradually, inch by inch, until the portion of the lower pipe we were raising had entered the 8 inch pipe, when the hoisting apparatus was found strong enough to raise them out of the well.

The difficulty experienced in raising this pipe after its adhesion to the walls of the well had been broken, and it had started on its upward journey, made one realize the amount of friction which would have to be overcome in the work which remained to be accomplished. The rods brought up on this occasion 79 feet 3 inches of pipe; this last above the block was filled with water, mud, rocks, and small pieces of sheet-iron. The surface of the pipe was pressed in and broken through in several places, apparently by a loose rock between the pipe and walls of the well, which worked its way up as the pipe ascended.

During one night the well caved at a distance of 1,079 feet 3 inches from surface, so as to cover up the top of lower pipe 40 feet. We bored through this *débris*, but the sides caved as the drill descended, and it was raised from the well with difficulty. After many attempts the well was cleared out to a certain distance, and, being left overnight, caved so that we were occupied during the whole of the following day in drilling through the rock and earth which had fallen in and choked up the well-bore. No difficulty was experienced in boring through the *débris* which seemed to fill the well during the night, but the tools became en-

cumbered with caves which occurred during the day, so that the lever had to lift, in boring, not only the rods and drill, but a large mass of rock and earth at each stroke. On stopping work at night, as a precautionary measure, the tools had to be drawn up into the 8-inch pipe for fear they would be buried, so that we could not get them out of the well. The pump was constantly bringing up a full load on each occasion, but the more matter removed from the well, the more seemed to fall into it from this unseen source nearly a quarter of a mile below us. It would be a matter of repetition to describe the efforts made and tools employed to remove the effects of the caving and to deepen the well-hole so as to withdraw the 253 feet of pipe still in it. All the above proved useless, and the situation was a desperate one.

The condition of the well was as follows: From the bottom of 8-inch to the top of 7-inch pipe, a distance of 160 feet 3 inches, the walls of well were unprotected and had caved in, filling up the pipe and bore of well to a distance of 377 feet 10 inches. Forty feet of this filling was above the pipe and prevented our tools from reaching it. There remained in the well below this mass of rock and earth 253 feet 6 inches of pipe, and below this again 35 feet 1 inch of bore unprotected by pipe. An experienced well-borer from Pennsylvania, who witnessed the futile attempts made to remove these quicksands, as you might call them, said, if such an accident had occurred in the oil regions, that the workmen would immediately abandon the hole and sink another one. This accident leaves the well in a situation which will require time and money to rectify it, but its consequences are far from irreparable. The best method to insure success in removing these incumbrances from the well will be to lower a 7-inch pipe, with a lip on its outside surface, until the bottom of it rests on top of pipe now in well. Then the pipe in well can be cleared through this of the products of the cavings and of the broken drill in bottom of well-hole. We can then take hold of it with the expanding tool (described on page 692, Report of Chief of Ordnance, 1877) by allowing the tool to pass down, so that the cutters could expand and take hold under the steel ring at the bottom of the old pipe. The new pipe could be raised by wooden clamps around the outside of it, and the old pipe by the large iron rods one and a half inch square. Both should ascend simultaneously, so that the bottom of the new pipe should rest, until it entered the 8-inch pipe, on the top of the lower pipe. This would protect the well from the caving of its sides. From the above position the upper pipe could be raised first and then the lower one.



The above plan, which is the best that suggested itself to my mind, required for its execution more time than would elapse before the expiration of the fiscal year, when the work would have to be discontinued, as Congress had not made any appropriation to continue it during the present year. Under these circumstances it would be folly to put any more pipe in the well only to become a fixture there, which would cost money and time to extricate. It was determined, therefore, to purchase some more wire rope and the tools which would be needed to complete this work, and to repair all the pipe which had been taken from the well.

As the analysis of the water obtained from the 1,407-foot level was not very encouraging, it was decided to make arrangements to utilize that which came from the stream which was met with at 960 feet from

the surface. In order to effect this it would be necessary to stop the water which entered the well at the 1,407-foot level from rising and mixing with the better water obtained at the lesser depth. The bore was already filled up 377 feet above the lower source of water with earth, &c. This mass was rammed down to increase its density, then a number of grain-sacks made into wads were pressed down on top of it. Above these we lowered and spread out three barrels of cement and two barrels of sand, and allowed a week to elapse to give these time to settle down and to acquire the consistency of glue. Over the cement and sand we placed more sacks and pressed them down into this half-hardened substance expecting that the material of which the bags were made would bind the mass together into a solid water-tight bottom to the upper part of the well. In measuring some time afterwards the depth of these obstructions we ascertained that there were 6½ feet of this conglomerate on top of the filling which came from the caving of walls of well. When a sufficient time had elapsed for the cement to set and to harden the mass, the deep-well pump was lowered 300 feet into the well, and the piston-rod was connected with the lever, which was worked by the steam-cylinder. The water discharged at first was frothy, opaque, accompanied by gas which readily ignited at the mouth of the well; its temperature increased to 80° and the taste was unpleasant. The quantity delivered was estimated to be 1,000 gallons per hour. As the pumping was continued the gas gradually disappeared, the water becoming clear and soft; the unpleasant taste to a great extent was lost, and the temperature continued high. The water contains no lime nor any salt which might form a crust on the inside of the boilers; it can therefore be used in them and for irrigating purposes. The chemist reports that it contains organic matter, and is, therefore, unfit for food. The water was pumped continuously for forty-two hours and the quantity remained the same as at the beginning, while the quality improved. I have nearly completed a brass force-pump with a piston of 5 inches diameter, which will furnish, with the present machinery, about 3,000 gallons an hour. The above requires an expenditure of fuel, but the government can obtain an abundant supply of water from this well at a very low cost. An appropriation of $800 to build a windmill over this well would enable us to obtain a supply of water with which we might defy the dry season of California and its withering effects on all verdure.

It has been suggested to me by some parties that when we commence to use this water freely, the traces of organic matter in it may disappear, and then it will be useful for all purposes; and it has also occurred to me that we could increase the supply of water, or might even obtain a flowing well of sufficient capacity to supply the wants of this post, by opening the fissures in the strata at the 960-foot level. This could be effected by exploding a cartridge of giant powder or nitro-glycerine at this depth by means of an electric current. I hear that this plan is frequently adopted in the oil regions to increase the flow of oil from a well when it begins to fail, and that it very often proves successful. There is one objection to the use of this plan, however, in the artesian well here, for if we fail to obtain a flowing well of sufficient capacity for our wants by this means, and have to sink the well deeper, then we may have some difficulty in passing this mine created by ourselves, because the surrounding strata, having been loosened by the explosion, will fall against the pipe and impede its progress downwards. If this was my private enterprise, I should adopt this plan as one that might probably afford a satisfactory solution to our endeavors to obtain artesian water.

In this connection it might be well to state that I applied to Colonel Mendall, of the United States Engineers, to ascertain if he had any means at his disposal for firing a mine under water, and found that he had a magneto-electric machine (Beardslee's) which could furnish a current of high intensity, but on that very account it needed perfect insulation; the wire that he had was old and unfit for my purpose; he kindly offered to lend me the wire and the machine. As the cartridge and a portion of the wire had to be used at the depth of 970 feet, they would be subjected to a pressure of 450 pounds to the square inch. This pressure would require a small Atlantic cable to resist it, and I was fortunate in finding in the United States Coast and Geodetic Survey Office, in San Francisco, an insulated cable which was brought out here by Professor Agassiz for taking temperatures at great depths. The use of this was kindly offered to me by Professor Davidson of the United States Coast Survey Department. The above suggestion of exploding a cartridge just below the 8-inch pipe in the well is submitted for your consideration, and you will perceive that, owing to the kindness of friends, it can be carried out with a small expense to the Ordnance Department.

I have proved by the above that we can readily remove all the obstructions now in the well, and our former achievements in boring at great depths demonstrate that we can sink the well to any required distance. Machinery, tools, and pipe are all prepared to bore the well to a depth of 2,073 feet, and we only wait for a further appropriation to continue the work.

APPENDIX M.

MEASUREMENT OF POWDER PRESSURES IN CANNON BY COMPRESSION OF OIL. DR. W. E. WOODBRIDGE.

(Eleven plates.)

EXPERIMENTS AT WASHINGTON ARSENAL, 1854–'55.

WASHINGTON, *January* 18, 1853.

SIR: I have recently constructed an apparatus designed to ascertain the pressure per square inch exerted by fired gunpowder, either within a cannon charged in the ordinary manner, or otherwise confined.

In the method I have devised it is proposed to measure the force of the explosion by the registered compression of a liquid contained within a piezometer, which is secured within a gun while it is discharged. The compression thus produced is compared with the compression produced by submitting the instrument to a known pressure by means of a hydrostatic apparatus (which I also possess), and the actual pressure is deduced from the comparison.

I have made a small number of experiments with the instrument mentioned, but am not in possession of the means of giving the experiments the completeness which would result from the employment of guns of different calibers.

The determination of the pressure of fired gunpowder under the various conditions of its use in service appears to me to have, in addition to its scientific interest, an important practical bearing on the subject of gunnery; and with this view, I very respectfully request the aid of your department in making some further experiments. No great expenditure would, I think, be demanded to conduct the experiments to useful results. The employment of guns already in service and the expenditure of the requisite ammunition would be the principal items of expense.

I am, sir, very respectfully, your obedient servant,

W. E. WOODBRIDGE.

Col. HENRY K. CRAIG,
Chief of the Ordnance Department.

WASHINGTON ARSENAL, *January* 22, 1853.

SIR: In reply to your letter of the 20th instant, relative to the experiments proposed by Dr. Woodbridge for measuring the force of fired gunpowder, I have to say: That the determination of the pressure exerted by the elastic gases produced by the combustion of gunpowder is an element of the first importance in the theory and practice of gunnery, and the measure of this pressure is indispensable in all mathematical computations of the effects of gunpowder on the projectile or on the gun. The only experiments on this subject, of which I have any knowledge, are those of Count Rumford, and they are accordingly still referred

to by mathematicians in all discussions relative to the force of fired gunpowder. (See Piobert, "*Traité d'Artillerie.*") But interesting and curious as these experiments were, the deductions made from them are liable to many objections, on account of obvious causes of error and uncertainty in the results, and an accurate solution of the questions involved in them is still highly desirable for scientific and practical purposes.

Dr. Woodbridge has explained to me the method which he proposes to employ for accomplishing this object. He informs me that an instrument constructed on a somewhat similar principle was used by Perkins in his experiments on the compressibility of liquids, and Dr. Woodbridge has tested his own apparatus by some trials, on a moderate scale, which appear to him satisfactory. Under these circumstances, therefore, and without entering into a minute discussion of the proposed plan, I am of opinion that a further trial is worthy of the attention of the Ordnance Department. It would be curious, and creditable to the department as well as to the inventor, if another American philosopher should perfect the work so well begun by Rumford.

With regard to the probable cost of prosecuting these experiments to a useful extent it is difficult for me to form an estimate at this time. The guns which might be used for the purpose would have to be afterwards classed as unfit for ordinary service, but I think that guns of old pattern, and condemned on that account as unserviceable, might be made use of for these experiments, and the gunpowder, shot, and other materials would involve very little cost. Dr. Woodbridge ought to receive some remuneration for his expenses during the time he may devote to the work; the other expenditures for labor and workmanship would be but small, and I should think that the sum of $500 would defray all the expenses (exclusive of the guns and ammunition) which it would be necessary to incur in obtaining many interesting and useful results, if the experiments should be made at an arsenal.

A few preliminary trials, involving very little cost, would serve to test the sufficiency of the proposed apparatus and the general accuracy of the results to be expected from its use. I hope, therefore, that you may feel justified in furnishing Dr. Woodbridge with the means of prosecuting his experiments on this interesting subject.

Dr. Woodbridge's letter is herewith returned.

Respectfully, your obedient servant,

A. MORDECAI,
Captain Ordnance, Brevet Major.

Col. H. K. CRAIG,
Ordnance Department.

[First indorsement.]

ORDNANCE OFFICE, *January* 24, 1853.

Respectfully submitted to the Secretary of War. I regard the proposed experiments as highly interesting both in a scientific and practical point of view, and recommend that they be authorized as suggested in this letter; the actual expenditures (not to exceed $500) to be defrayed from the appropriation for "ordnance service," which is applicable to the purpose.

H. K. CRAIG,
Colonel Ordnance.

[Second indorsement.]

Approved.

C. M. CONRAD,
Secretary of War.

JANUARY 28, 1853.

PERTH AMBOY, *December* 18, 1855.

SIR: I send herewith an account of the experiments on the pressure of fired gunpowder, undertaken in accordance with a notice of their authorization received from your department in February, 1853, together with their results and such particulars as are of interest in the present stage of the experiments. The results present, I suppose, the most accurate knowledge we have upon the particular subject to which they relate, and the experiments have served to afford instructions, such as are generally gained only from experience, which would be of much value in a more extended course if they should be made. Various engagements, both on the part of Major Mordecai, with whom I have had the pleasure and honor to be associated, and on my part, have been the necessary cause of delay. * * *

Very respectfully, your obedient servant,

W. E. WOODBRIDGE.

Col. H. K. CRAIG,
Chief of Ordnance Department.

WASHINGTON, *November* 3, 1856.

COLONEL: I present herewith a report of Dr. Woodbridge, containing a description, with drawings, of the apparatus used by him in determining the compressibility of oil in connection with the experiments on the pressure of fired gunpowder, which were made at the Washington Arsenal whilst I was in command there. This report, the previous one of Dr. Woodbridge on the same subject, and a printed paper prepared by him for Silliman's Journal (a copy of which is also inclosed herewith), present a full view of the method used, and the results obtained thus far in these experiments. They are to be regarded only as preliminary trials of the proposed method of operating on this interesting subject, and I do not consider them as having been carried far enough to enable us to pronounce definitively on the accuracy of the indications given by the instruments used in the gun for determining the pressure against the sides of the bore. But the results thus far obtained are, I think, sufficiently encouraging to authorize a continuance of the experiments on a subject which is of great importance in reference to the form of cannon, and especially to the best mode of proving them.

I may remark here that this subject has engaged the attention of the intelligent corps of artillery of Prussia. A report of their experiments was published in December, 1853, in the "*Archives of the Artillery and Engineer Corps*" (Vol. 34, Part 2), and a translation of the paper into French will be found in the first volume of the "*Technologie Militaire*," 1854, published in Belgium by Lieutenant-Colonel Delobel, a copy of which is among the books brought out by the military commission recently returned from Europe. The method adopted in these Prussian experiments appears to have been almost exactly the same as that pur-

sued in similar investigations under the direction of Colonel Bomford at Boston—a method much less direct and satisfactory in its application than that of Dr. Woodbridge, if the latter should, on further trial, be found perfectly reliable. * * *

Respectfully, your obedient servant,

A. MORDECAI,
Major of Ordnance.

Col. H. K. CRAIG,
Ordnance Department.

In reporting to the Secretary of War on November 11, 1856, on the application of Dr. Woodbridge for reimbursement of moneys expended by him, which exceeded the amount assigned by the War Department to the purposes of the experiments, the Colonel of Ordnance stated that his intention in making a favorable recommendation was, in part, "to hold out to him (Dr. W.) fair inducements to prosecute a work which an able and experienced officer of this department considers as affording prospects of decided utility in its future operations."

ACCOUNT OF EXPERIMENTS.

[*The account of the experiments referred to in Dr. Woodbridge's letter of December* 18, 1855, *is here combined, in substance, with a later and in some respects more full communication made to Major Mordecai, and by him forwarded to the Chief of Ordnance under cover of his letter dated November* 3, 1856.]

It was proposed in these experiments to ascertain the pressure of the gases evolved by the combustion of gunpowder, by including in the cavity within which the pressure should be restrained a piezometer, which, by registering the compression of a liquid contained within it, should afford an indication of the pressure to which it had been exposed.

This instrument, as employed in these experiments, is a small cylindrical vessel of steel, inclosing a quantity of oil destined to receive the pressure of the fluid by which it may be surrounded, through the medium of a piston which is carried inward a distance proportional to the amount of compression. To the piston is attached a stem of wire, extending inward, on one side of which a fine point is made to press, inscribing, when the piston is moved, a line on the stem equal in length to the extent of its motion.

The details of its construction were arranged with reference to obtaining as large capacity and as great length of stroke as its exterior dimensions would permit—to fixing the proper relations between the volume of oil required to fill it, the area of the piston, and the range of pressures to which it was to be subjected—and to its being easily filled without including air.

The piezometer made use of in the firing recorded under date of November 27, 1854, in the accompanying table, was made in the fall of 1852, and used at that time to test its working, for a few firings with a four-pounder gun, at Perth Amboy, N. J. The closed end of the instrument terminated in a screw half an inch in diameter, designed to secure it to the bottom of the gun, where it was inserted in a hole tapped to

receive it. The screw was broken in the first experiment, though the instrument retained the record of the compression.

A second piezometer, similar to the first, but attached by a screw of the full diameter of the body of the instrument (one inch), was employed in the second and third rounds, breaking in the third.

The original design in inserting the instrument in the manner mentioned above was to avoid injuring the gun used in these trials in a way that would render it unserviceable.

The third piezometer, used without injury in all the subsequent experiments, was inclosed, when used, in a hollow plug of steel screwed into the side of the gun, the cavity of the plug and the bore of the gun being in communication.

It was essentially like its predecessors, excepting that the attaching-screw was omitted. It is represented in full size in the accompanying drawing (Plate I). Figure 1 is a section through its axis; Fig. 2, an exterior side view; Fig. 3, a view of the end placed, when in use, toward the bore of the gun; Fig. 4, of the opposite end, and Fig. 5, a view of the piston with its stem, separately. The same letters are used in referring to like parts in each of the figures. A is the body of the instrument. The general form of its lower (or outer) end is hemispherical, but it is flattened on four sides (as at *a* and *a*) for fitting a socket attached to the middle of a small oil-pan used in filling it. B is the barrel to which the piston is fitted. It screws freely into the body, and makes with it a close joint; *b* and *b* are holes for the wrench or screw-driver. C is the piston, packed with a leather ring occupying the groove *l*, Fig. 5; *c* is the eye of the piston, by means of which it is withdrawn or turned when required. A special implement (not represented) is fitted to the eye for this manipulation. D is a stem screwed into the piston. The lower end is squared, to fit a socket like that of a watch-key. As it is desirable to use a new stem for each experiment, special appliances were prepared for making duplicates readily and with accuracy. They are coated with a thin film of black varnish to render the marks they are to receive more distinct. E is the point from which the stem receives the mark recording compression. F is a tubular support for the point, and also a guide for the stem of the piston. To it is attached the spring G, pressing the point against the stem; *f f* are holes in the support to permit the oil within it to escape freely when the stem is suddenly thrust in, under the action of surrounding pressure. H is a screw permitting the escape of oil when the instrument is being "set" for use, but also capable of closing tightly the opening in which it is situated. Tests were made of the tightness of the piston and of the joints.

Figure 6 represents, in section, the hollow steel screw-plug for receiving the piezometer. It is fitted to holes in the gun, and inserted at the point where it is desired so ascertain the pressure. A ring, K K, is screwed into its open end to retain the inclosed instrument.

In preparing the piezometer for an experiment, two items are to be specially observed; it must contain no air, and the "setting," or adjustment of the quantity of oil contained, must be done at the precise temperature the instrument is to have at the moment of firing.

The procedure is as follows: All the parts are first oiled, over their whole surfaces. The adjusting-screw is inserted into the body of the instrument, which is then set upright in a socket attached to the middle of a small pan intended to catch any overflow, and is nearly or quite filled with oil, which should be made to flow down the side of the cavity rather than in a stream. The support of the marking-point, quite clean

but covered with oil, is now screwed into its place, with the aid of a special implement, not described. When this is withdrawn, it will be necessary to replace the oil caused to overflow by its insertion. The barrel is now slowly put in its place and screwed firmly down. The hole in the piston for receiving the stem is filled with oil, the stem screwed in, and the piston inserted in the barrel. The adjusting-screw is loosened a little, permitting the piston to be pressed just below the top of the barrel, and again tightened. The next step is to bring the instrument and its contents to the setting temperature. For this purpose a water-bath (a common wooden pail) was provided; a narrow tin cup, deeper than the bath and weighted at the bottom so as to stand upright within it; and a pair of wooden pinchers for handling the piezometer, which instrument could be inserted in them in such a way as to be nearly enveloped and yet to leave the adjusting-screw and piston readily accessible. The piezometer, seized in the pinchers, is placed at the bottom of the cup in company with the tools to be used in setting it, and is covered with a loose wad of cotton. The cup is set in the middle of the bath and surrounded with water kept as nearly as possible at the desired temperature, for a sufficient time to impart, as nearly as appreciable, the same to the instrument. It is then withdrawn, the screw loosened, the piston depressed a little to a regulated depth with a special tool, the screw tightened, and the piston rotated a few degrees, which completes the setting. The object of this last movement is to inscribe a transverse line on the stem, affording a starting point in measuring the length of the stroke.

Small changes of temperature after the instrument is set are of no consequence, as the oil will of course return to the same volume, and the piston stand at the same place, on returning to the same temperature.

Before placing the piezometer in the hollow plug, a thin leather envelope, kept saturated with oil, is drawn upon it (with the intention of affording protection against the shock of firing), and when inserted, the remaining space within the plug is filled with oil, which is retained by stopping the opening through the retaining-ring (which forms the communication with the bore of the gun) with a loosely-fitted disk of cork or leather.

One particular to be noted is the position of the eye of the piston with reference to the line in which the gun will recoil on firing. The metal surrounding the eye occupies a position at one side of the piston's axis of rotation in the barrel, thereby throwing the center of gyration out of that line; and if that center be so situated as to fall outside of a plane coincident with the line of recoil, it is evident that the piston will have a tendency to rotation when the gun is fired. It was apprehended that this rotation might interfere with the proper marking of the stem, or accurate measurement of the mark, and for that reason care was usually taken to place the piston in such position that its center of gyration should be nearly in the plane just mentioned, and forward of its axis of rotation. Curious and instructive results, hereafter mentioned, were, however, obtained through the accidental omission of this precaution.

After firing, the length of the stroke was measured under a compound microscope by the application of a scale divided into thousandths of an inch and capable of being read to ten-thousandths.

The volume of oil subjected to pressure, the area of the piston, and the length of stroke being known, we derive from them the degree of compression. To complete the data for ascertaining the pressure to which the piezometer has been exposed in any given case, it becomes

necessary to determine the relation of compression to the pressure required to effect it.

The experiments made for this purpose were conducted with a good deal of care to secure accuracy, and were somewhat elaborate.

The following account of them is designed to be sufficiently minute to afford an opportunity for judging of the accuracy of their results. It will be necessary to begin with some description of the apparatus:

The compressing pump, though an essential part of the apparatus, need not be very fully described. Several additional drawings would be required for a complete description; and so far as its function of supplying pressure only is concerned, its construction is perhaps not very intimately connected with the accuracy of the results. Its barrel is of cast steel, placed horizontally, its exterior diameter being 2″.2 and that of its bore 0″.7. The piston, which is also of cast steel, tempered, is forced in and retracted by means of a square-threaded steel screw 1″.5 in diameter.

These parts are placed in a strong frame of iron. The screw is turned by means of a ratchet-wheel, which forms its head, and a lever and pawl connected with it. To facilitate the retraction of the piston a crank is attached. Screw-valves prevent, during the alternate movements of the piston, the escape of the liquid through the aperture by which it enters the barrel, and its return from the receiver into which it is forced. A safety-valve of tempered steel, ground to a seat, also in hardened steel, with its graduated lever and weight, is attached to the pump and serves for measuring the pressures it is made to exert.

The construction and arrangement of the safety-valve and connected parts are shown in the drawings (Plate II).

Fig. 1 is a vertical section of a portion of the pump through the center of the valve, and perpendicular to the axis of the barrel. F is a prolongation of the barrel upon which the valve is mounted. D is the valve, fitted to its seat in the cup-shaped top of the screw E, which is perforated through its axis to communicate with the bore of the pump. It is also fitted into the cap C in such a way as to allow it to rotate freely, in order that it may be ground to the seat in the exact position in which it is to be used. Fig. 2 is a view of the valve and cap, at right angles with the section. An obtuse knife-edge at the top of the cap receives the pressure of the lever A. The valve, cap, and screw are all of tempered steel. B is the pin on which the lever turns. It is tempered and polished. The end of the lever is also tempered as far as its bearing on the valve, and the hole for the pin is polished. This mode of construction probably secures a nearly uniform ratio between the friction and pressure under different strains. G is the weight. The line of suspension is made to coincide with one of the faces of the stirrup, so that its relation to the graduations of the lever may be easily seen.

Gauges constructed upon the plan just described are, at their best, subject to two sources of uncertainty: The friction of the pin, and the impossibility of determining by measurement the area of that part of the valve actually receiving pressure.

For reasons which will be hereafter mentioned, this safety-valve was used in the measurements of the highest pressures employed, not, however, without previous comparison with another gauge designed to avoid the defects just mentioned, and specially constructed for use in these experiments. It will be called the *valvular gauge*, for convenience of distinction from other gauges to be subsequently described.

Fig. 3 (Plate III) presents a front elevation of this instrument, and Fig. 4 (Plate IV) gives a section at right angles to the plane of projec-

tion in Fig. 3 of the valve and the parts most nearly connected with it, on a larger scale. The valve, marked V, and represented separately in Fig. 5, is of hardened steel, and is inserted in a stem of steel, D, which is supported on its sides, at its upper end, by passing through the screw A in the cross-piece B. The lower part of the valve enters the cavity *e* a short distance, closing it by contact with the sides of its circular orifice. This cavity receives the liquid transmitting the pressure, which is communicated through the tube C. The block E, into which the cavity is drilled, is also of casts teel and hardened at its upper part. The valve was ground to its seat with flour of emery and finished with crocus, by rotating it in its place. The screw through which the upper end of the valve-stem passes is fitted to a tapering hole in the cross-piece, and being slitted through its axis, the parts which support the stem may be made to approximate each other at pleasure. Both the upper part of the stem and the bearing parts of the screw are tempered and polished, and the adjustment is such as to avoid friction and oscillation in any perceptible degree. The valve V has a conical cavity, *v*, at its upper side, to receive the point *f* of the hook F, by which the weights with which the valve is to be loaded are suspended. This point is also conical, being slightly more acute than the apex of the cavity, which last is situated as accurately as possible over the center of the area receiving the pressure of the liquid. The form of the valve is the result of several trials, and although from its general shape it might be expected to wedge into its seat, it is not found to do so, but is raised after hard pressure with no more force than is required to lift its weight. The bearing surface of the valve in contact with its seat is too narrow to allow of easily determining its precise form. The block E, into which the cavity *e* is drilled, is supported by the iron frame H H (Fig. 3), which rests on the larger wooden one, K K.

Three scale-pans of different sizes, for receiving the weights, are required, as the larger ones would alone, in some cases, be too heavy for the desired pressure. The lightest, Fig. 6 (Plate V), is used for pressures not more than 500 pounds to the square inch; the medium (Fig. 7), for pressures from 500 to 600 pounds; the heaviest, J, Fig. 3 (Plate III), designed for higher pressures, is represented as suspended in place by the hooks F L. In order to avoid danger of injuring the instrument in placing large weights on the scale, it is detached by raising it with a lever inserted under the pin *l* in the lower hook, using M as a fulcrum, and turning back the loop G, when it may be allowed to rest on supports placed under it. Six 50-pound weights, four of 10-pound, and one of 5 pounds, represented in Figs. 8, 9, and 10 (Plate V), were made for use with the instrument. They are of cast iron, turned and adjusted by comparison with the standards at Trenton, furnished to the State of New Jersey by the United States Department of Weights and Measures. The smaller weights made use of were not all of exactly their nominal weight, but where differences existed they were accurately known. The weights of the valves, hooks and scales were also carefully ascertained.

A comparison of the pressure of a column of mercury of known height with the weight on the valve of the gauge required to balance it, was adopted as the most accurate method of determining the relation between the weights to be placed on the scales and the desired pressures per square inch. It therefore became necessary to construct an instrument for the purpose.

The mercurial pressure-gauge consists of a cistern of glass containing mercury, and a series of perpendicular glass tubes attached to a gradu-

ated staff and joined continuously together, extending to the height of 52 feet. The tubes are so connected with the cistern that by pressure upon the surface of the mercury it may be forced to ascend the tubes.

In Figs. 11 and 12 (Plate VI), C represents the cistern, which is connected at the bottom to a foot, B, by which it is securely attached to the floor of the basement, through the intervention of the piece of timber, A. An iron cap, D, is cemented to its neck, and is drilled so as to afford continuous passages, through the tubes *c* (Fig. 12) and *d* (Fig. 11), from near the bottom of the cistern to the foot of the staff E, and from the orifice *s* (which is connected with the source of pressure) to the surface of the mercury within. The tube *c* is of glass, cemented into the cap D, and terminates near the bottom of the cistern. *d* is an iron tube screwed tightly into the cap, and forming the communication between the cistern and tubes for receiving the column of mercury. These tubes are supported by a wooden staff composed of five pieces (one to each tube), provided at their ends with suitable coupling-irons and screws for joining them together, as represented in Figs. 13 and 14, in which E and E are the staff, F F, Fig. 13, the tubes, and G G the couplings. Fig. 15 is an end view of one of the pieces, showing the horizontal outline of the coupling and (by the inner dotted lines) a horizontal section of the staff. A broad angular groove in the front side of the staff allows the tubes a protected situation. Each tube is a little shorter than the section of staff to which it is attached, extending nearly through the castings at the ends, into which they were at first cemented. It was, however, found necessary to substitute stuffing-boxes, one of which is represented in section, Fig. 16. Two rings, one of vulcanized India rubber and one of leather, formed the stuffing. The faces of the couplings adjoining each other were brought to a plane surface in the lathe, and the joining of the tubes made perfect by interposing a ring of very thin sheet-rubber before screwing the couplings together.

The glass tubes were drawn for the purpose, and those most nearly alike in diameter of bore were selected, to equalize, as nearly as possible, the effect of capillary repulsion. Their internal diameter is about one-tenth of an inch.

The staff is marked into divisions of one foot in length, the measurements being transferred with much care from a rule divided at the United States Department of Weights and Measures. A short scale, divided into inches and fractions, was used for measuring the height of the mercurial column between these lines. Pressure was applied by means of the pump represented at M, Fig. 17 (Plate VII), which need not be described.

Although the cementing of the cap to the cistern was tested at a higher pressure than it could receive in the use for which it was designed, it failed to remain tight—a defect which it became necessary to remedy by a kind of stuffing-box applied to the neck of the cistern, which it is not thought necessary to represent in the drawing. A signal-bell, at the foot of the instrument, and a cord running up by the side of the staff to the garret, afforded means of communication from the observer above to the operator below. When the arrangement was completed, the control of the height of the column was such as to allow of giving, at pleasure, many varying degrees of convexity to the surface of the mercury rising from the end of the topmost tube when full.

Five thermometers, hanging against the staff (one in each story of the building), were employed to ascertain the temperature of the column.

The specific gravity of the mercury made use of, according to my determination, was, at 60°, 13.589, water at 60° being 1.

In computing the pressure of the column, its height from the surface of the mercury in the cistern was taken, and the counteracting pressure of the weight of the oil by which the pressure was applied was allowed for in proportion to its height and specific gravity.

The first comparisons between the valvular and mercurial pressure-gauges were made by placing them in direct communication with each other and the pump—a mode which for accuracy leaves nothing to be desired; but, on account of the tediousness and expense of resorting to the mercurial gauge (which was unavoidably located about three-quarters of a mile from the workshop) to test each modification of the valve, another plan was afterwards adopted.

An instrument was prepared in which the volume of air at the temperature of 32° was noted for each foot in height of the mercurial column in the upper part of its scale. Fig. 18 (Plate VII) represents the instrument, which is chiefly of glass. The pressure is communicated through the tube B, which is cemented into a steel connecting-screw, A. E is a quantity of mercury transmitting the pressure to the air to be compressed, which is principally contained in the part F at the ordinary pressure of the atmosphere, but under pressure occupies only the tube C, or a portion of it. This tube, though nearly cylindric exteriorly, has a tapering bore, largest at the bottom, and vanishing at *c*—the design being to equalize as far as possible the spaces representing equal increments of the height of the mercurial column. The scale D is of brass, divided into 160 parts, and attached to the tube by two bands. Only the upper one, *d*, pinches the tube, to avoid its displacement by the expansions and contractions occurring with changes of temperature. To detect any error in the position of the scale, a mark is made on the tube, corresponding with the top of the sale. Fig. 17 represents the arrangements for the use of the instrument. C is a water-bath, in which it is surrounded by a current of ice-cold rain-water flowing from the pail A, and passing out from the bottom of the bath by a siphon not shown in the figure. The bath is a glass tube closed at the bottom, attached to a foot, D, and furnished with a wooden dish, B, at the top. The water escaping by the siphon runs upon ice, and is returned at frequent intervals to the pail. Both this and the dish at the top of the bath are constantly supplied with ice. E and G are tubes communicating between the air pressure gauge and the pump, and also, through the tube F, with the mercurial or with the valvular pressure-gauge, as desired. The cup K is used for replenishing the pump with oil--the liquid used for communicating pressure. A screw-cock, L (nearly concealed, in the drawing, by other parts of the apparatus), is interposed between the pump and the gauges. H is a stand for the support ot the cock.

The instrument just described (distinguished by the name of "air-gauge"), when graduated by comparison with the mercurial gauge, could be depended on for indications substantially identical with those of the latter, and saved much labor in the work of perfecting the valvular gauge, which involved many alterations. This last instrument could, of course, only be compared with the others mentioned within the limits of their range of pressures, which was but little more than twenty atmospheres. These comparisons were, however, sufficient to establish the ratio between pressures indicated and weights applied. After the form of the valve was changed to that shown in the drawing (Fig. 4) already referred to, its action was very uniform. A weight of 59.323 grains on the area of the valve was found equivalent to a pressure of one pound per square inch.

As a test of the uniformity of the action of the valvular gauge at

pressures somewhat higher than the mercurial gauge could indicate, it was connected with the manometric gauge shown in Fig. 19, which was capable of indicating a pressure of one hundred atmospheres, and, having been constructed very accurately, it also served to give corroborative evidence of the accuracy of the computed relations between the pressure per square inch and the weights on the valve.

A table was prepared, giving the weight in grains, which must be placed in the appropriate scale for each 100 pounds per square inch up to 15,000 pounds. It may be well to remark that all the arithmetical operations were proved. It was customary also that the individual weights employed for a given pressure should be designated by two persons separately, to avoid errors.

Having now a reliable means of measuring the pressures to be applied, we pass to the experiments relative to the compression of oil.

However reasonable a confidence in the indications of the steel piezometer before described might be in such experiments, there was one query in regard to them which it was desirable to answer conclusively: "Does not enough leakage occur about the piston, during the comparatively long time required for an experiment on compression, to seriously lessen the recorded amount?"

The most satisfactory reply to all doubts of this kind was evidently to be found in an independent experiment, free from the conditions which might be deemed objectionable in the use of the instrument mentioned; and if the progress of compression could be actually seen up to a very considerable pressure, it was evidently desirable. The apparatus which will now be described was devised with that object.

It consists, principally, of a glass instrument for containing the oil subjected to experiment, and a receiver inclosing it, provided with windows through which the changes of volume could be viewed up to a pressure of 10,000 pounds per square inch.

The glass instrument is represented (in full size) in Fig. 20 (Plate VIII). It is a graduated tube, terminating in an elongated bulb, C, and having a piston, *p*, fitted to its bore, which is very nearly 0′.038 in diameter. The tube was selected as having a uniform bore, and the divisions were marked by means of a dividing machine. When carefully tested by columns of mercury, occupying successively different parts of the bore, they were found to be of apparently uniform capacity. The numbering commences at the bottom, and the lines and figures, which are cut upon the glass, were blackened to render them more conspicuous. The capacity of the bulb and tube to 0 of the scale equals 3566.3 divisions of the tube. Fig. 21 represents the piston and a portion of the tube on an enlarged scale. The groove *m* is occupied by a ring of mercury, which, as a result of the cohesion of its particles and consequent tendency to assume a surface the most nearly spherical which its position will permit, acts as a most perfect packing for such extremely small pressure as is required to overcome its friction. The sharp outline of the lower side of the piston is favorable to accurate observation. The proper proportion between the bore of the tube and the capacity of the bulb was learned from previous experiments. A rack, B (the teeth of which are on the side not in view), is attached to the piezometer by a band, A, and when acted on by a pinion connected with the receiver in which the instrument is inclosed during the experiments, serves to bring any desired portion of the graduated tube opposite the windows for observation.

The receiver is represented in Fig. 22. Two iron tubes, F and K, are

screwed into the opposite sides of a central block of iron, G, which is cubic in its general form, but has short cylindrical projections from the upper and lower sides, into which the tubes are inserted. The block is drilled through vertically, making a communication between the tubes of the full size of their bores. The outlines of the bores of the tubes and other parts, as they would be seen in section, are given in dotted lines. The lower end of the tube K is closed by a solid steel screw, L. To the upper end of the tube F is fitted a steel screw, E, drilled through its center, and connecting the receiver to the brass tube D communicating with the compressing pump and pressure-gauge. Two glass windows, one for observation and the other for the admission of the necessary light, are situated in two opposite sides of the block G. The position of one is shown at J. They are made in the form of a truncated cone (but having their bases chamfered, as represented in Fig. 23), and are fitted to conical cavities with their bases inward. Fig. 24, which is a horizontal section, at full size, through the center of the windows (as well as through the axis of the pinion), will give an idea of the manner in which they are inserted; N and N are the glasses. The shaft O of the pinion P is fitted into the screw H, entering the side of the receiver in a mode which will be understood by inspection of the drawing. The outer end of the shaft is squared, to be received into a socket. The rack attached to the glass piezometer is held into gear with the pinion by a portion of the inner end of the screw brought into the form of a guide for that purpose. A portion of the rack with the pinion is represented in Fig. 25.* The water-bath for regulating the temperature of the receiver and its contents is represented in Fig. 26. It is a rectangular box, made of sheet tin, and incased in ½-inch boards. It has windows to correspond with those of the receiver. The receiver, of which the position is shown by the dotted lines is supported by a shelf immediately below the windows, having a circular hole to receive it. A short tube, R, projects from the side of the bath, opposite to the shaft of the pinion. Into this is inserted a cork, through which is passed a shaft, S, having a socket to fit the squared end of the pinion-shaft, and a milled head, T, by which it may be turned.

The glass piezometer is filled with oil for compression by forcing it through a small tube descending through the bore and nearly to the bottom of the bulb of the instrument, which is placed perpendicularly to permit the escape of the air. The stream of oil must be continued while the small tube is withdrawn, so that it may leave no vacuity.

The introduction of the piston with its packing is accomplished thus: After placing the instrument horizontally, a small quantity of mercury (enough to occupy a space two or three times the diameter of the bore in length) is made to occupy the intended place of the piston by the aid of a suitable syringe. The piston is then introduced and passed, by

* In first testing this receiver by pressure, the glass inserted in the screw M began to show signs of fracture at a pressure of about 5,000 pounds per square inch, but kept in its place, leaking not faster than a drop per minute, at a pressure of nearly 10,000 pounds. On removing the glass it was found to be split into curved laminæ, forming arches from opposite sides of the cavity to which it was fitted. The parts were not entirely separated, but adhered in their original form. From the appearance of the fracture it was supposed that the fitting had not been sufficiently exact, and another glass was fitted with special care. This began to fail at about the same pressure as the other, and at a pressure between 7,000 and 8,000 pounds per square inch it shot from its place, being crushed into sand. After a renewed examination into the cause of failure, it was found that the steel screw into which the window was fitted was slightly sprung from its proper form in consequence of a want of sufficiently accurate workmanship. This was remedied and another glass fitted, which remains, as does the one in the opposite side of the receiver, without visible injury.

means of a wire, through the oil, meeting with extremely slight resistance until it reaches the mercury. When it touches the mercury, the open end of the instrument should be depressed, and the piston pushed in until there remains but a very small globule which has not passed the inner face of the piston, its grooves being filled. The diameter of the globule may be estimated very nearly by comparison with the bore of the tube, and allowance made for the diminution of the capacity of the instrument which it occasions. Its compressibility differs so little from that of the glass that the amount would be inappreciable. The mercury which has passed the piston should be removed by a syringe and the instrument returned to its perpendicular position, when the globule before mentioned will of course fall to the bottom.

Before placing this instrument in the receiver, its open end was covered by a loosely-fitting cap, to prevent the little particles liable to be washed from the connecting-tubes from entering it and perhaps clogging the piston in its upward movements:

When the instrument was properly inclosed, the rack being attached to it and in gear with the pinion, the remaining space in the receiver was filled with oil, and the whole was placed in the bath, as represented in Fig. 26; connected with the pump and pressure-gauge; and covered with water at the temperature of 60° Fahr., which was the temperature employed in the first experiments. Any perceptible variation from this was corrected or prevented by the addition of small quantities of water at a lower temperature, the apartment being a few degrees warmer than the bath. The water was put in frequent motion by a dasher moved perpendicularly, that the heat might be equably distributed. A "chemical thermometer" of tolerable accuracy was used to determine the temperature (the same which was made the standard in the use of the guns), and was constantly viewed in the same position.

At 60° the oil stood, before the application of pressure, at 195.9 on the scale of the instrument. The decimal parts of a division are given from estimation only, but a practiced eye need never make an error of 0.1. The attainment of the desired pressure in any case was known with equal readiness to both the person working the pump, whose duty it was to observe the pressure-gauge also, and the observer of the compression—to the former by the rather sudden escape of a little oil at the valve, and to the latter by a corresponding short retrocession of the piston. After first bringing the pressure to the desired degree, it was slowly repeated several times, to afford an opportunity for accurate observation of the lowest point attained, which was immediately noted.

The experiments on the compression of oil at 50° were made in precisely the same way and without any alteration of the apparatus. The irregularity occurring between the pressures of 7,500 pounds and 8,000 pounds induced a repetition of that part of the experiments, but no error could be found in the weights or otherwise.

The following table gives the height of the oil in the instrument at given pressures and both temperatures:

Compression of oil under visual observation.

Pressure.	Height of oil in divisions of instrument.	
Pounds per square inch.	At 60° Fahrenheit. (1 division = $\frac{1}{3762.2}$ of volume.)	At 50° Fahrenheit. (1 division = $\frac{1}{3746.4}$ of volume.)
0	195.9	180.1
500	189.5	173.6
600	188.0	......
700	186.4	......
800	185.3	......
900	183.8	......
1,000	182.4	167.9
1,500	177.0	162.4
2,000	170.2	155.0
2,500	163.4	148.6
3,000	157.5	142.5
3,500	151.3	138.5
4,000	145.7	132.9
4,500	140.0	127.0
5,000	134.1	120.2
5,500	128.6	114.9
6,000	123.3	109.9
6,500	118.0	104.1
7,000	112.0	98.9
7,500	106.8	93.9
8,000	102.9	83.5
8,500	96.2	77.9
9,000	91.1	71.3
9,500	85.9	65.0
10,000	80.8	59.8

The limits of the strength of the connecting tubes were known not to much exceed 10,000 pounds per square inch, and for that reason the pressure was not, at first, carried higher; but after completing these experiments it was attempted to increase it, and the result was the bursting of one of the tubes. After replacing this, the trial was renewed with the same result. The remaining experiments were made with the steel piezometer inclosed in the cast-steel receiver represented in Fig. 27, which could be connected with the pump by a much stronger tube. The absence of tubes of sufficient strength for connecting the pump with the valvular gauge led to the use of the safety-valve of the pump for measuring the higher pressures. That this might be done with as much accuracy as possible, careful comparisons were made between it and the first-named gauge up to 10,000 pounds. The piezometer was filled and set in the same manner as for use in the gun. The receiver was immersed in a water-bath kept at the proper temperature.

The pressures, temperatures, and length of stroke are given below.

Compression of oil in steel piezometer.

Pressure.	Length of stroke at—	
Per square inch.	60°	50°
Pounds.	*Inches.*	*Inches.*
10,000	0.2148	0.2401
15,000	0.2780	0.3266
20,000	0.3656	0.4108
25,000	......	0.5670

A comparison of the apparent compression of the oil in the glass instrument with that of the oil in the steel piezometer at the same temperature and pressure (60° and 10,000 pounds per square inch), shows

it to be greater in the latter instrument—a variation which is in the opposite direction from that which would occur from leakage of the piston during compression.

In the glass instrument the apparent compression amounts to 3.059 per cent.; in the steel one (as computed from the weight of oil contained, its specific gravity and consequent volume, and the measured diameter of the piston) to 3.273 per cent.—the difference being about one-fifteenth. This may be accounted for by supposing the steel to be less compressible than the glass to that extent.

It was thought most proper to assume the strokes of the steel piezometer to be the true indices of the pressure to which it was subjected, and to consider the indications of the glass instrument as proportional. In accordance with this idea the following table was made, which presents the compression as observed in the glass piezometer in multiples of the capacity of one division of the tube, and the corresponding stroke of the steel piezometer.

Compressibility of oil in glass and in steel piezometer compared.

Pressure.	Compressibility at 60° in—		Compressibility at 50° in—	
Pounds per square inch.	Multiples of $\frac{1}{3762.2}$	Stroke of steel piezometer.	Multiples of $\frac{1}{3746.4}$	Stroke of piezometer.
		Inches.		*Inches.*
500	6.4	0.01194	6.5	0.01297
600	7.9	.01474	......	....
700	9.5	.01773	......	....
800	10.6	.01978	......	....
900	12.1	.02258	......	....
1,000	13.5	.02519	12.2	.02435
1,500	18.9	.03527	17.7	.03533
2,000	25.7	.04796	25.1	.0501
2,500	32.5	.06065	31.5	.06287
3,000	38.4	.07166	37.6	.07505
3,500	44.6	.08324	41.6	.08303
4,000	50.2	.09369	47.2	.09421
4,500	55.9	.1043	53.1	.10598
5,000	61.8	.1135	59.9	.11956
5,500	67.3	.1256	65.2	.13014
6,000	72.6	.1355	70.2	.14011
6,500	77.9	.1456	76.0	.15169
7,000	83.9	.1566	81.2	.16207
7,500	89.1	.1663	86.2	.17225
8,000	93.9	.1752	96.6	.19281
8,500	99.7	.1861	102.2	.20399
9,000	104.8	.1956	108.8	.21716
9,500	110.0	.2053	115.1	.22974
10,000	115.1	.2148	120.3	.2401

In order to give these results a form in which they would be easily applicable, they were expressed by geometrical construction, on the same scale as they are given in the accompanying diagram (Plate IX), on plan-paper accurately printed, in squares of $\frac{1}{10}$ inch, from an engraved plate. The line of compression at 60° is drawn in full line, and at 50° in dotted line.

As will be seen by inspection of the diagram, pressure is represented by horizontal distance, and compression by vertical. Each tenth of an inch of the stroke of the piezometer-piston is represented by two inches of vertical measurement, and each thousand pounds by one inch horizontally.

The pressures in the table, subsequently given, of the results of experiments on the pressure of fired gunpowder, were taken from this

geometrical table, which may be read with considerable certainty to intervals of five pounds.

There remains to be noticed in this connection the necessity of a correction of the pressure as derived from the length of the stroke of the piezometer when produced by the sudden action of gunpowder. The compression of a fluid is attended with the evolution of more or less heat. If the compression is slowly produced, and the fluid is in contact with good conductors, the heat so generated will be carried off nearly as fast as it is produced, and no perceptible elevation of temperature may result. If, however, the compression is suddenly effected, the heat evolved, having no time for diffusion, elevates the temperature. This rise of temperature reduces the extent of compression by an amount equal to the expansion which would be due to that temperature applied to the fluid under the pressure employed. The amount of this difference has not yet been ascertained, but data which lack the precision necessary to exact results indicate that the correction due to this cause, which increases with both depression of the temperature of the liquid compressed and increase of pressure, is not unimportant. No attempt has been made, however, to introduce this correction into the results subsequently presented of the experiments with the piezometer. The subject has been reserved in hope of future experiments, for which apparatus has been partially prepared.

We now arrive at the experiments in which the piezometer was used to record the compressions produced by the pressure of fired gunpowder under various conditions, and from which the pressures were to be derived. They were made at Washington Arsenal, District of Columbia, commanded by Maj. Alfred Mordecai, whose hearty co-operation in their conduct demands thankful recognition.

Two six-pounder guns, one of iron, the other of bronze, were used in these experiments. The diameter of the bore of each, at the seat of the shot, was 3″.69, very nearly. The iron gun was used in the first three experiments, in which the piezometer was attached to the bottom of the bore. It was afterward pierced through its side to receive the piezometer inclosed, as already described, in a hollow steel plug, the center of the opening being 1″.5 forward of the bottom of the bore. It was used in this form in several experiments. The bronze gun was, however, used in the greater number. It was pierced with nine holes at different distances from the bottom, beginning at 1 inch and ending with 47.8, as shown in the accompanying drawing (Plate X) and specified in the accompanying tables. They were arranged alternately to the right and left of the central vertical plane, in the upper half of the gun, and inclined 45° to that plane.

A solid plug was fitted to each hole, and was withdrawn only to permit the insertion of the piezometer.

Small holes to receive a thermometer with an elongated bulb were drilled near the openings mentioned above, extending to within a short distance from the bore.

Several experiments were made to ascertain pressures in a musket barrel. A portion of the bore at the breech end was enlarged enough to receive the piezometer, and was separated from the forward portion by a ring screwed to place and a leather disk closing its opening, as described in connection with the hollow plug. The piezometer was introduced from the rear, the surrounding space filled with oil, and the breech-plug inserted afterward. A vent of the normal size was drilled just forward of the partition formed by the ring and disk just mentioned.

It has already been intimated that the temperature at which the pie-

zometer was set was that at which the gun was to be fired. In the earlier experiments the method by which it was intended to effect this was by inclosing the instrument, *ready* to be set, in the gun for a sufficient time to equalize their temperature—which was left to merely atmospheric influences. The instrument was then withdrawn, quickly set, and returned, and the gun fired without delay.

It was afterward found that the gun changed its temperature sensibly, from changes of wind and sky, in shorter intervals than was supposed. To avoid the errors liable to arise from this cause the practice was changed. The instrument was set at a determinate temperature, higher than that of the outside air but lower than that of the arsenal workshops. The gun was run into the shops (near by) for a short time in the interval between the experiments and made slightly warmer than the firing temperature. The piezometer was then properly inserted, the gun taken outside, and when cooled to the proper point the thermometer was removed and the gun fired by a primer already inserted.

The various charges used in the experiments, with the varied circumstances and results, are given in the following table:

Experiments on the pressure of fired gunpowder

Date.	Number.	Gun.	Charge.* Powder. Height.	Charge.* Powder. Weight.	Charge.* Cartridge bag.	Charge.* Shot. Weight.	Charge.* Shot. Diameter.	Distance of piezometer from bottom of bore.	Temperature of gun.	Stroke of piezometer piston.	Pressure per square inch.	Remarks.
			Inches.	*Pounds.*		*Pounds.*	*Inches.*	*Inches*	*Fahr.*	*Inches.*	*Pounds.*	
1854. Nov. 27	1	Iron.......	3.5	1.25	None ...	6.4	3.58	3.25	56°.75	0.376	9,640	*First piezometer* used; screwed to bottom of bore and covered with paper case to protect from heat of explosion. Space occupied by it, 2.372 cubic inches. Instrument broken, falling at muzzle of gun. Record of compression retained. Initial velocity of ball, taken by ballistic pendulum, by Major Mordecai, 1,407 feet per second.
Dec. 14	2	.....do	"	"	...do	6.32	"	"	54°	.55	10,140	*Second piezometer*; screwed to bottom of bore; covered as before. Space occupied by instrument, 2.756 cubic inches. Initial velocity, 1,401 feet.
Dec. 14	3	....do	"	"	...do	6.4	"	"	56°	Effaced.	....	Second piezometer. Instrument broken. Record lost. Initial velocity, 1,437 feet.
1855. Jan. 13	4	.....do	3.42	"	...do	6.33	"	1.5	55°.50	.2875	14,260	*Third piezometer.* Used in all the subsequent experiments.
Jan. 13	5	.....do	3.35	"	...do	"	"	"	50°	.3446	16,070	
Jan. 16	6	.....do	3.42	"	...do	6.39	"	"	54°	.3065	14,940	
Jan. 16	7	.....do	4.0	1.5	...do	6.32	"	"	53°	.3615	17,870	
Jan. 16	8	.....do	"	"	...do	6.33	"	"	50°	.3876	18,630	
Jan. 17	9	.....do	"	"	...do	6.29	"	"	47°	.3865	17,960	
Jan. 17	10	.....do	4.1	"	Merino .	6.25	3.57	"	51°	.3727	18,010	Cartridge-bags, full size of bore.
Jan. 17	11	.....do	"	"	...do	6.32	"	"	53°	.3680	18,290	Do.
Jan. 17	12	.....do	4.2	"	...do	6.28	"	"	54°.50	Indistinct	....	Do.
Jan. 18	13	Bronze....	4.55	"	...do	6.31	3.58	1.0	59°	.3965	20,810	Cartridge-bags, in this and all subsequent rounds, of merino. Weight, 0.015 pound. Diameter of former, 3″.375.
Jan. 18	14	.....do	"	"	...do	6.37	"	"	58°	.3965	20,630	
Jan. 18	15	.....do	4.35	"	...do	6.35	"	"	58°	.3860	19,810	
Jan. 19	16	.....do	4.55	"	...do	6.36	"	4.	56°	.317	16,100	
Jan. 19	17	.....do	"	"	...do	6.32	"	"	51°	.341	16,130	
Jan. 19	18	.....do	"	"	...do	6.40	"	"	51°	.3608	17,290	
Jan. 19	19	.....do	"	"	...do	6.36	3.575	7.8	50°	.224	9,280	
Jan. 19	20	.....do	"	"	...do	6.45	"	"	49°	.2411	9,870	
Jan. 20	21	.....do	"	"	...do	6.37	"	"	38°.50	.221	....	} The termination of the stroke of the piezometer was, in these cases, in some degree doubtful.
Jan. 20	22	.....do	"	"	...do	6.35	"	11.8	44°	.2015	7,820	
Jan. 20	23	.....do	"	"	...do	6.39	"	"	44°	.2055	7,970	
Jan. 20	24	.....do	"	"	...do	6.44	"	"	52°	.1691	7,440	

*Dupont's cannon powder, made in 1837, was used. The shot were strapped to sabots of the full size of the bore, unless otherwise specified

Experiments on the pressure of fired gunpowder—Continued.

Date.	Number.	Gun.	Charge. Powder. Height.	Charge. Powder. Weight.	Charge. Cartridge bag.	Charge. Shot. Weight.	Charge. Shot. Diameter.	Distance of piezometer from bottom of bore.	Temperature of gun.	Stroke of piezometer piston.	Pressure per square inch.	Remarks.
1855.			*Inches.*	*Pounds.*		*Pounds.*	*Inches.*	*Inches.*	*Fahr.*	*Inches.*	*Pounds.*	
Jan. 20	25	Bronze....	4.55	1.5	Merino .	6.38	3.575	15.8	55°	.1904	8,340	The *stroke* of this firing seemed to indicate five successive augmentations and diminutions of pressure, each less than the preceding, the stroke being repeated during the partial rotation of the piston. Some other strokes have, to some extent, the same character.
Jan. 20	26	.....do	"	"	...do	6.38	"	"	50°	.246	10,310	
Jan. 20	27	.....do	"	"	...do	6.39	"	"	50°.50	.2395	10,070	
Jan. 20	28	.....do	"	"	...do	6.37	"	"	51°.50	.243	10,330	Gun loaded and piezometer inserted in shop. Taken out and fired when it had cooled to the setting temperature of the instrument. *Subsequent firings the same.*
Jan. 27	29	.....do	"	"	...do	6.36	"	23.8	50°	.213	8,870	
Jan. 27	30	.....do	"	"	...do	6.19	"	"	50°	.2135	8,880	
Jan. 27	31	.....do	"	"	...do	6.34	"	"	49°.50	.204	8,550	
Jan. 27	32	.....do	"	"	...do	6.36	"	31.8	50°	.1575	6,790	
Jan. 29	33	.....do	"	"	...do	6.28	"	"	"	.1575	6,790	
Jan. 29	34	.....do	"	"	...do	6.36	"	"	"	.1658	7,210	
Jan. 30	35	.....do	"	"	...do	6.36	"	39.8	"	.1357	5,790	
Jan. 30	36	.....do	"	"	...do	6.38	"	"	"	.1284	5,430	
Jan. 30	37	.....do	"	"	...do	6.33	"	"	"	.1382	5,910	
Jan. 30	38	.....do	"	"	...do	6.35	"	47.8	"	.1404	6,010	
Jan. 30	39	.....do	"	"	...do	6.36	"	"	"	.1448	6,200	
Jan. 30	40	.....do	"	"	...do	6.31	"	"	"	.1303	5,510	
Jan. 30	41	.....do	"	"	...do	6.33	"	15.8	"	.2952	13,170	
Jan. 30	42	.....do	"	"	...do	6.42	"	"	"	.2830	12,480	
Jan. 30	43	.....do	"	"	...do	12.13	3.66	1.0	"	Vanish'g	....	Turned cylinder of iron instead of shot. The line on the stem of the piston, which should indicate the length of the stroke, vanishes without giving a distinct termination
Jan. 31	44	.....do	4.65	"	...do	....	....	"	"	.1295	5,480	
Jan. 31	45	.....do	6.05	2.0	...do	....	....	"	"	.2358	9,780	
Jan. 31	46	.....do	8.8	3.0	...do	....	....	"	"	.3234	14,820	
Jan. 31	47	.....do	4.425	1.5	...do	6.11	3.575	"	"	.3609	17,030	} Balls without sabots.
Jan. 31	48	.....do	4.475	"	...do	6.10	"	"	"	.3346	15,490	
Jan. 31	49	.....do	5.65	2.0	...do	6.33	"	"	"	.4276	20,540	
Jan. 31	50	.....do	5.65	"	...do	6.4	"	"	"	.4335	20,750	
Jan. 31	51	.....do	8.85	3.0	...do	6.43	"	"	"	.4790	22,220	

Feb.	1	52	....do....	4.53	1.5	...do....	6.4	"	11.8	"	.2481	10,460	
Feb.	1	53	....do....	"	"	...do....	6.44	"	"	"	.2343	9,720	
Feb.	1	54	Iron.......	4.48	"	...do....	12.07	3.66	1.5	"	Vanish'g	....	Cylinder instead of shot. See remark to No. 43.
Feb.	1	55	....do....	4.28	"	...do....	12.15	"	"	"	"	....	Do.
Feb.	1	56	....do....	4.38	"	...do....	12.16	"	"	"	"	....	Do.
Feb.	2	57	....do....	"	"	...do....	12.16	"	"	"	.4252	20,480	Cylinder instead of shot. Escape holes *ff* (see drawing of piezometer, Plate I) were enlarged. Marks on stem very distinct.
Feb.	2	58	....do....	"	"	...do....	12.14	"	"	"	.4828	20,720	
Feb.	2	59	....do....	"	"	...do....	12.15	"	"	60°	.3960	20,970	
					Grains.		*Grains.*						
Feb.	3	60	Musket barrel.	0.7	70	....	866	0.675	....	60°	.0655	2,730	Expanding ball without wad.
							With wad						
Feb.	3	61	....do....	1.18	110	....	420	.65	....	59°	.0900	3,820	Round ball with paper, as for cartridge.
Feb.	3	62	....do....	3.55	318	....	464	.675	....	60°	.2815	15,170	2d-proof charge for musket barrels. Weight of two wads, 19 grains.
Feb.	3	63	....do....	4.2	389	....	"	"	....	"	.3396	18,500	1st-proof charge.

Measurements of bronze gun before, during, and after the experiments.

Distance from muzzle.	Diameters. January 17, 1855.	Diameters. January 31, 1855, morning.	Diameters. February 13, 1855.	Distance from muzzle.	Diameters. January 17, 1855.	Diameters. January 31, 1855, morning.	Diameters. February 13, 1855.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
53	3.69	3.71	3.72	35	....	....	....
52	3.69	3.71	3.73	34	3.682	3.692	3.694
51	3.69	3.711	3.743	33	....	....	....
50	3.69	3.72	3.75	32	3.683	3.690	3.69
49	3.693	3.715	3.752	31	....	....	....
48	3.698	3.709	3.755	30	3.681	3.688	3.69
47	3.709	3.715	3.758	28	3.683	3.683	3.685
46	3.710	3.722	3.768	26	3.682	3.680	3.682
45¾	....	3.735	3.770	24	3.690	3.685	3.70
45	3.720	3.722	3.76	22	3.685	3.686	3.695
44	3.725	3.728	3.757	20	3.700	3.730	3.71
43	3.725	3.733	3.745	18	3.712	3.713	3.71
42	3.715	3.735	3.74	16	3.705	3.714	3.702
41	3.71	3.730	3.735	14	3.702	3.701	3.702
40	3.71	3.735	3.73	12	3.690	3.698	3.69
39	....	....	3.72	10	3.688	3.685	3.69
38	3.70	3.735	3.702	5	3.728	3.710	3.71
37	....	....	....	0	3.760	3.755	3.75
36	3.69	3.690	3.698				

Length of bore, 54.8 inches; from face of muzzle to reinforce, 28.84 inches; length of reinforce, 27.7 inches; diameters of reinforce, 9 and 9.7 inches. (See Plate X.)

Measurements of iron gun before and after the experiments.

Distance from muzzle.	Diameters. December 14, 1854.	Diameters. February 13, 1855.	Distance from muzzle.	Diameters. December 14, 1854.	Diameters. February 13, 1855.	Distance from muzzle.	Diameters. December 14, 1854.	Diameters. February 13, 1855.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
46	3.705	3.705	35	3.696	3.697	24	3.680	3.680
45	3.692	3.69	34	3.700	3.698	22	....	3.680
44	3.699	3.70	33	3.698	3.697	20	....	3.680
43	3.692	3.695	32	3.700	3.698	18	....	3.71
42	3.695	3.695	31	3.702	3.691	16	....	3.702
41	3.695	3.695	30	3.693	3.689	14	....	3.702
40	3.698	3.697	29	3.690	....	12	....	3.69
39	3.698	3.69	28	3.685	3.685	10	....	3.69
38	3.698	3.696	27	3.683	....	5	....	3.71
37	3.699	3.696	26	3.683	3.680	0	....	3.75
36	3.698	3.697	25	3.680	....			

Length of bore, 47.5 inches.

It will be noticed that in four instances the stroke of the piston was undetermined in consequence of the "vanishing" of the line on the piston-stem without distinct termination. After a little consideration, the cause assigned to this occurrence was that under particularly heavy pressures, producing a long and quick stroke, the escape of the oil from the tubular support of the marking-point (caused by the entrance of the piston-stem) was so much resisted in consequence of the want of sufficient escape-holes that a pressure sufficient to wholly counteract that of the spring on the marking-point was brought to bear upon it from within. That this was a correct conclusion, seems to have been attested by the results following the enlargement of the escape-holes, as noted in the table.

* * * * * * *

According to our experiments, the maximum pressures which different portions of the sides of the bore of the gun must sustain, with a given charge, do not always diminish with their increased distance from the bottom of the bore. This has been thought to cast doubt on the correctness of the indications.

That the pressure at each particular part of the bore does not regularly reach its height and continuously decline, will, it is believed, appear from an examination into the movements of the gases in the gun.

To begin with the simplest case, we will suppose the gases to occupy a space which remains for a sensible time the same. That the tension of the gases behind the ball is not uniform might be expected, and will appear from the indications of our instrument in the experiments.*

The average pressure indicated at different distances from the bottom of the bore, the charge being in each case $1\frac{1}{2}$ pounds of powder, in a cartridge-bag, and one 6-pounder shot, is given below:

Distance from the bottom of bore.		Pressure per sq. in.	
1-inch	(bronze gun)	20,210	pounds.
$1\frac{1}{4}$ "	(iron gun)	18,150	"
4 "	(bronze gun)	16,510	"

The condition of the gases will be represented in the diagram of the bore and its contents, given below, by marking the space they are supposed to occupy with lines varying in breadth according to the tension.

It is evident that a difference of tension amounting to 3,800 pounds in the distance of 3 inches will not allow the gases to remain in quiescence, but must give rise to vibrations of great force, and alternations of tension such as are represented in the diagrams 1st and 2d. A just impression of their force requires the recollection that the weight of the gases is the same as that of the powder from which they were generated.

Fig. 1

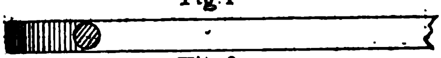
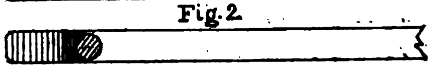
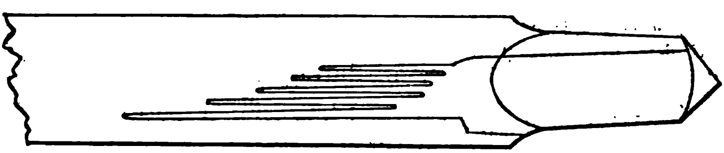


Fig. 2

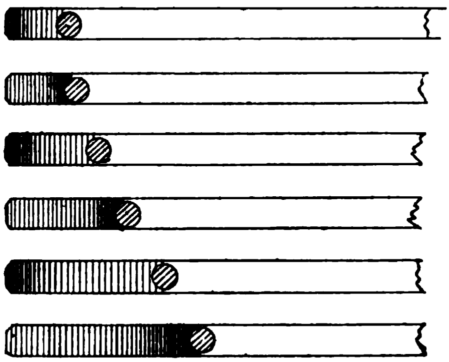


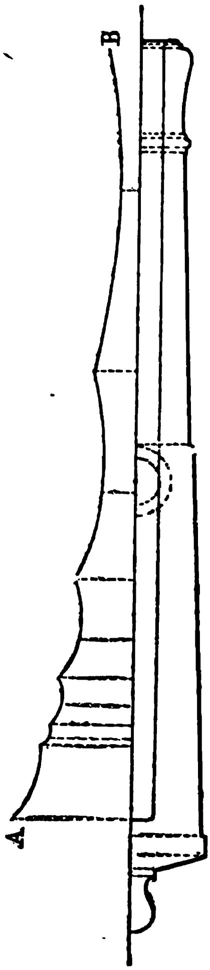


Evidences of vibration are to be seen in the marks on some of the piezometer wires. The center of gravity of the piston does not lie in the line of its axis, and in some cases the recoil of the gun has caused a partial rotation of the piston during the formation of the line on its stem. The sketch in the margin represents, proximately, a line on one of the wires (as it appears under the microscope), the piston having rotated nearly 90° during its formation. The effect of an enlargement of the space during the vibration, such as actually occurs, will evidently be to increase the amplitude of the vibrations and to diminish their frequency

*The cause of this difference of tension will be found in the reaction of the expanding gases of the forward part of the charge upon that in the rear; each stratum of powder opposing the expansion of that behind it not only by its dead inertia, but by making it, so to speak, a *point d'appui* in giving motion to its own particles. The effect of this cause is strikingly exhibited by the pressures exerted near the bottom of the bore by different blank charges. The pressure indicated by the piezometer at 1 inch from the bottom was: with $1\frac{1}{4}$ lbs. powder, 5,480 lbs. per square inch; with 2 lbs., 9,780; with 3 lbs., 14,820.

and force. The amount of this effect, and the number of vibrations occurring before the ball leaves the gun, will depend, other things being equal, on the weight of the ball. The figures below are designed to illustrate the character of the variations of tension occurring while the ball is leaving the bore:





Adopting another mode of illustration and representing tension by perpendicular distance from a horizontal line—the waved line A B will denote the maximum pressure sustained by the different parts of the bore. The supposed limits of the cavity during the successive vibrations are given in vertical lines. If a true explanation of the action of the gases has been given, there will be no difficulty in accounting for the fact that the indications of our instrument do not give the pressures at different parts of the bore the order of their distances from the bottom, as do the pistol-ball velocities obtained in the experiments made with Colonel Bomford's apparatus at Watertown Arsenal in 1842. The latter present a comparative indication of the average rather than the maximum pressure during its action on the balls.

The capability of the piezometer to measure pressures of much more brief duration than the time of the passage of the ball through the pistol-barrel will appear from a comparison of the inertia to be overcome in each case. The weight of the piston and stem is 20 grains, and the resistance of the inertia of the oil is equivalent to that of about 36 additional grains, while the weight of the pistol-ball is 218 grains. After taking into account the differences of area and the mode of action in the two cases, I think it may be safely concluded that the piston will have reached its extreme position as soon, at least, as the ball has passed through the same distance.

The superior practical importance of determining the *greatest* instead of the *average* pressure upon the sides of the bore, with reference to the construction of guns, is evident from the fact that the strength of the gun must be adapted to the former and not to the latter. The inadequacy of the mode of determining, even relatively, the amount of pressures of very brief duration by the initial velocities of balls projected by them is shown by the effects of detonating powders used in fire-arms:

the barrel may be shattered while the ball is thrown with comparatively little force.

The effect of increasing the charge of powder, compared with that of increasing the weight of the projectile, in augmenting the pressure was unexpected, and has to some seemed almost incredible; although, as is not surprising in regard to a subject of such a nature, opposite views are held by men thoroughly conversant with artillery.

The mean of the pressures indicated at 1 inch from the bottom of the bore, with a charge of 1½ pounds of powder and a ball weighing, with its sabot, 6.3 pounds nearly, was	20,210	pounds.
With the same charge, at 1½ inches from the bottom	18,150	"
With 1½ pounds powder and a shot weighing 12.15 pounds, at 1½ inches from bottom	20,743	"
With 2 pounds powder and a ball of 6.36 pounds, at 1 inch from bottom.	20,640	"
With 3 pounds powder and a ball of 6.43 pounds, at 1 inch from bottom.	22,220	"

The pressure in the cases in which shot of 12.15 pounds weight were used, reduced to that which would be indicated at 1 inch from the bottom of the bore, on the supposition that the same difference would exist as with the smaller charges, would be 22,700 pounds, indicating that the effect of doubling the weight of the ball (but with diminished windage) is not very different from doubling the weight of the powder—instead of increasing the pressure in a much greater ratio, as some have supposed.

The results of the experiments with the musket-barrel accord, so far as they admit of comparison, with those just stated. The manner in which an increased charge of powder may be supposed to affect the pressure has already been referred to, and illustrated by reference to the experiments with blank charges. The resistance of the forming gases in that part of the charge which is least confined, to the expansion of those in other parts of the charge, is perhaps most strikingly illustrated by the action of the fulminates, which, in quantities of a few grains, will, as is well known, tear in pieces a brass or copper plate upon which they are gently heated.

The variations of pressure sustained by the gun when fired with charges very nearly the same are greater, as might be expected, than the variations of initial velocity imparted to the ball under similar circumstances.

When the combustion of the powder takes place with more than average rapidity, the pressure in the first instants of the explosion is augmented, but its action on the ball is not so well sustained as in the case in which the combustion is more slow and consequently longer continued.

The following table of initial velocities of 6-pounder balls, extracted from a table in Major Mordecai's "Second Report" of his experiments on gunpowder, will serve for the comparison:

Initial velocities of balls fired from a 6-pounder gun.

Powder.		Shot.		Initial velocity.	
Weight.	Height.	Weight.	Diam.		
Pounds.	*Inches.*	*Pounds.*	*Inches.*	*Ft. per sec'd.*	
1.5	4.8	6.11	3.58	1,594	
1.5	4.8	6.15	"	1,580	
1.5	4.9	6.13	"	1,553	
1.5		6.26	"	1,538	Fixed ammunition.
1.5		6.37	"	1,498	Fixed ammunition.
1.5		6.3	"	1,526	Fixed ammunition.

Extract from an article "On the Pressure of Fired Gunpowder in its Practical Applications," by William E. Woodbridge, M. D., American Journal of Science and Arts, September, 1856, *referred to in Major Mordecai's letter of November* 3, 1856.

[After reference to the experiments of Count Rumford, who estimated the pressure of gunpowder fired in a space which it filled at not less than 54,750 atmospheres—from an erroneous estimate of the strength of his eprouvette, which was burst by the charge—the following experiment is given:]

"The following experiment seems to show that the extreme force of gunpowder fired in small quantities does not exceed 6,200 atmospheres.

"I inclosed in a hollow cylinder of cast steel, $1\frac{1}{8}$ inches in exterior diameter and one-fourth of an inch in diameter interiorly, 20 grains of Hazzard's Kentucky rifle powder, which filled, loosely, the cavity. This was fired by a flash of powder penetrating through the aperture of a valve (of steel) opening inward, but designed to prevent the escape of gas outward. The cylinder was not ruptured, and, being put under water, no gas was found to escape (the weight of the instrument was too great to test the loss of gas by my scales). On pressing in the valve by means of a screw, an abundance of gas escaped, carrying with it the odor of sulphuretted hydrogen. The seat of the valve was found to remain perfect; a fact which, when compared with a former trial in which the gases escaped in consequence of a slight defect of the valve, is presumptive proof of its immediate action. The residuum was found to weigh 10.45 grains. The calculated strength of the cylinder would be equal to an internal pressure of about 93,000 pounds per square inch, or 6,200 atmospheres of 15 pounds."

REMARKS.

WASHINGTON, *November* 20, 1878.

SIR: In the account of experiments on the pressure of fired gunpowder which I had the honor to furnish to your predecessor in command of the Ordnance Department in the year 1855, and which I learn is about to be printed, there is mention of a correction necessary to render the indications of a piezometer exact, and an intimation of data ascertained, which, though not sufficiently precise to afford exact results, nevertheless showed that the correction was not unimportant.

It was at that time hoped that further experiments would be instituted to determine this correction with accuracy. Since this has not been done it may be of interest to state the method by which the data referred to were obtained and the principles by which they were applied in reaching the conclusion stated.

I have done this in the accompanying communication, adding some suggestions as to a proper mode of supplying the correction spoken of, and as to the relative accuracy of the method of measuring powder-pressures by the compression of a liquid.

I have the honor to remain, very respectfully, your obedient servant,

W. E. WOODBRIDGE.

General S. V. BENÉT,
Chief of Ordnance.

Remarks on the "correction" referred to in the preceding account of experiments on the pressure of fired gunpowder, and on the relative accuracy of themethod therein described.

When the experiments on the compressibility of oil inclosed in glass (forming part of the experiments on the pressure of fired gunpowder in 1854–'55) had been completed, two further experiments were made with the same apparatus (see Plate VIII), continuing in the same condition. The object was to ascertain, for each of the temperatures adopted, to what extent the compressed oil, released from a pressure of 10,000 pounds per square inch as quickly as could be done with safety to the adjustment of the instruments, would regain its former volume at the instant of release—that is, before it should have time to absorb sufficient heat from the surroundings to sensibly change the lowered temperature resulting from the conversion of heat into mechanical energy during expansion.

After applying the designated pressure and maintaining it for some time at the selected temperature, 50° or 60°, that part of the scale of the instrument containing the oil which was expected to show the temporary arrest of expansive action was brought into the field of vision, the valve controlling the connection between the receiver and the pump was closed and the outlet valve opened. For a moment, in either case, the piston became stationary at several divisions of the scale below the position it occupied when the original temperature and volume were restored. I regret that the record of these experiments is not now accessible, but the exact figures are not essential to a consideration of the principles involved. Let it be supposed (for the present purpose) that on quick release from a pressure of 10,000 pounds, at a temperature of 60°, the piston stands, for the moment, at 6 divisions of the scale lower than it did at the beginning of the experiment, which may not be far from the actual occurrence. By reference to the table of "compression under visual observation" [see p. 724] (which may in fact be considered as potentially a table of expansions at the various pressures noted), it will be seen that the difference in volume or expansion between 50° and 60°, at the atmospheric pressure, was 15.8 divisions, or 1.58 for each degree.

A depression of 6 divisions will therefore correspond to a diminution of temperature of 3°.8, or an actual temperature of 56°.2.

Since *work* and *heat* are mutually convertible, it follows that oil at the temperature of 56°.2 submitted to a pressure of 10,000 pounds applied so rapidly that, virtually, no heat is lost by diffusion to surrounding objects (which is the case in the application of the piezometer to the measurement of gunpowder pressure), its temperature will be raised to 60°. It will thus appear that, in the instance supposed (in which the temperature of the oil is 56°.2 at the outset), the true pressure must be read from the column of the table giving compressions at 60°, for that is really the temperature at which the compression is effected.

To make the results obtained in the use of the piezometer strictly comparable with the facts before us, that instrument should be *set* (that is, the oil should be brought to and fixed at the standard volume) at 60° and submitted to pressure at 56°.2.*

If, then, with the piezometer set at 60° and exposed to the pressure of the gases in the gun at 56°.2, we obtain a stroke of 0''.251 (the equivalent of 80.8 at 60° in the table), we refer to the curve of compressions at 60° and find that the pressure was 10,000 pounds.

*This method was not practiced in the experiments made in 1854–'55, but it changes nothing in the principles involved, and presents a simpler case for comparison with the experiments from which the table of compressions is derived.

In this way we have, in this case constructed to meet our data, arrived at the corrected pressure.

We may now turn to the indication of pressure uncorrected by reference to the effects of the change of temperature resulting from compression, which is to be derived by interpolation from the data given in the table before referred to, as follows:

The "height of oil" in the instrument under 10,000 pounds' pressure to the square inch and at the temperature of 60° we find to be at 80.8 of the scale. With the same pressure and a temperature of 50° we find it to be at 59.8. The difference is 21 divisions of the scale. Supposing the rate of expansion under the pressure mentioned to be uniform, the rate is 2.1 divisions for each degree Fahr., so that at 56°.2 the oil would stand at 72.82. In the same way we find that, under pressure of 9,000 pounds per square inch and at 56°.2, the oil would stand at 83.576, giving a difference of height of 10.756 divisions for 1,000 pounds difference of pressure, so that each division represents a pressure of 92.9 pounds. But the stroke of the piezometer is equivalent to 80.8 of the scale, which is 8.02 divisions above the point to which, we have seen, it would be carried by a continued application of 10,000 pounds' pressure per square inch, and therefore indicates a pressure (uncorrected) of 9,255 pounds, or 745 pounds less than the true one.

It is probable that a more suitable oil might have been selected for the experiments; or at least that the compression at 50° would have been more regular had the oil been *strained* at a lower temperature than that employed in its preparation.

It can hardly be doubted that a considerable part of the compression apparent under the higher pressures at 50° must be attributed to the solidification of a portion of the oil. If this be so, the method of interpolation employed above probably carries the volume of oil at 56°.2 much too far toward that at 50° under the same pressure, and renders the hypothetical error stated above considerably larger than it really should be.

A series of experiments like those above mentioned on the volume and temperature of oil quickly released from pressure would, if carefully made, and covering sufficiently high pressures, afford all the data requisite for a complete table of the corrections necessary.

Another method, however, which will be described briefly, would be more easy in execution and more direct in its application. It may perhaps be said to obviate the necessity of a correction rather than to supply it. The accompanying drawing of a portion of the apparatus required (Plate XI) will facilitate the explanation.

A A is a strong receiver (represented by a vertical section through the center of its diameter), to be charged with compressed air forced through the passage *a*, which is also the means of communication with the necessary valves and pressure-gauge. A tube or barrel, B B, is screwed into the lower end of the receiver. It is accurately bored, and fitted with two pistons, C and D. The upper piston, C, inserted into the top of the barrel, is adapted to a short motion only, and is restrained from descending by an enlargement or shoulder resting on the upper end of the barrel. It should be as light as is consistent with strength sufficient to resist the pressure it may be required to bear, and should be surrounded with a small quantity of oil.

The office of the receiver and piston C is to supply a spring capable of opposing a regulated, and, within short limits, a nearly constant re-

sistance to the pressure of a liquid to be forced up below it by means of the piston D.

As the particular mechanism for operating that piston is not essential if it serves to apply the pressure as quickly as may be required and to release it as readily, it is not necessary to enter into a particular description. In general terms it may be stated that the requirements can be fulfilled by means of a single heavy spring, brought at will to the necessary flexure and tension by the operation of a screw, and so arranged that it may be instantaneously released—first, from the restraint which prevents its action on the piston, and then from all flexure, by which the piston would be wholly relieved from pressure.

The manner of using the apparatus would be as follows: Having decided upon the pressure and temperature at which the experiment is to be made, air is forced into the receiver until some excess of pressure is obtained. The lower piston having been removed, the "piezometer," properly filled and "set," is placed within the barrel and the piston inserted after it. The two pistons D and C should be left separated by a distance somewhat greater than the length of the piezometer, for a reason which will presently appear. The vacuity between them is filled with oil introduced through the passage *d* in the piston D, air escaping through the passage *p* (drilled in the barrel) until the space is filled, when the passages are closed by screws.

The receiver, barrel, and contents are now to be brought to the chosen temperature (with the aid of a water-bath) and the pressure adjusted by the release of a sufficient quantity of air from the receiver. When this is done the piston D is forced rapidly in (by means of the mechanism previously referred to) to such a distance as shall slightly raise the piston C, and then quickly released.

In this operation the oil between the pistons, with the piezometer and its contents, will have been subjected to the same pressure as that sustained by the receiver. The time occupied in doing it will have been quite too small for any appreciable diffusion of the heat generated by compression, and the record of the piezometer will be just that which it would have been if subjected to equal pressure in a gun.

A sufficient number of experiments conducted in this way, with different pressures and temperatures, would supply the data for constructing numerical tables or curves expressing the relations between piezometer-strokes and the pressures producing them, and needing no correction when applied to gunpowder pressures.

In conducting a series of such experiments the work would be greatly expedited by beginning with the highest pressures and lowest temperatures; because the adjustments of pressures could be made by successive diminutions of the quantity of air contained in the receiver.

There are, of course, precautions and details which cannot be noticed in this sketch, though their recognition is important in practice.

For reasons which will be stated, I regard the method of ascertaining powder pressures by the registered compression of a liquid as capable of greater accuracy than those which are based upon indentation or other change of form in pieces of metal acted on by a piston receiving the pressure to be measured.

The effect of the rise of temperature resulting from compression on the *extent* of compression has, of course, a definite relation to the pressure causing it; and this relation is susceptible of accurate determination, or, of elimination, by different methods.

This correction being supplied or rendered unnecessary, the only remaining inquiry which can be of importance to the indications of the

piezometer described in the preceding papers relates to the influence of the inertia of the piston in modifying the length of its stroke.

The amount of this influence, which varies with the rate of augmentation of the pressure acting on the piston, is incapable of determination, since that rate cannot be known.

The error is common to both classes of instruments mentioned, and can be reduced to a minimum only by employing the least weight of metal in the piston that is compatible with the performance of its functions.

In devising the concave spiral pressure-gauge described in Appendix F to the Report of the Chief of Ordnance, 1875 (page 135, Plate 5), reference was had to this requirement. Yet the piston is, and must remain, many times heavier than that of the piezometer, the weight of which might be further reduced. In one case, the piston is an instrument subjected to violent strains, and therefore requires to be strong; while in the other its action is merely that of a *septum* between the definite quantity of oil of which the compression is to be registered and that lying without, and having no other work to do than to overcome the friction of the "stem" under the pressure of the "marking-point."

The superiority of a liquid, employed as proposed, over a piece of metal to be changed in form, arises principally from the greater simplicity of its mechanical characteristics.

Disks of metal, though perfectly pure, or of an alloy exact in composition, and at the same time perfectly sound, may offer great variations in different specimens and in different parts of the same specimen—in hardness, in tensile strength, in elasticity of form (distinguished from elasticity of volume), in ductility, and in the property sometimes called "metallic viscosity," or "rate of flow" under pressure.

None of these are properties of a perfect liquid. Variation in any one of them will in some degree change the indications of pressure given by the gauge in which the disks are used; and no individual test can be applied without rendering the pieces useless. The best that can be done is to prepare them with as nearly uniform mechanical treatment as possible, concluding with careful annealing.

Complete soundness, that is, perfect interior union, is a condition more rare than is often supposed, and unperceived variations in respect to this quality may lead to great errors in some forms of instrument.

An important source of error in the indications of the best forms of indenting or crushing gauges arises from the uncertainty attending the "rate of flow"—which, in its relations to the employment of these instruments, presents a problem which must lack, in each case, one of the elements necessary to its solution, namely, the *time* in which the change is wrought.

The evident exemption of the gauge employing compression of a liquid from so many errors, apparently without the substitution of others, must, it would seem, give it a superior claim to accuracy, though it cannot, of course, be used with the same *facility* as the indenting or crushing gauges.

There would be no difficulty in adapting such an instrument for use as an "internal" gauge. In using it some time would be required to assure a correspondence between the temperature of the instrument and that of the gun, as the former temperature would be taken from the latter, unless some device might be employed in connection with the instrument for recording the temperature at the moment of firing—which need not be considered improbable.

PIEZOMETER

FIG. 1.

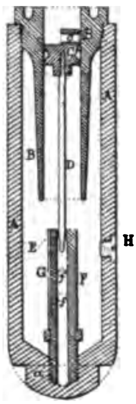


FIG. 2.

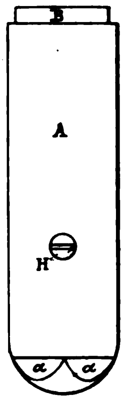


FIG. 3.

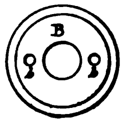


FIG. 4.

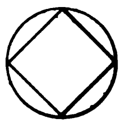


FIG. 5.

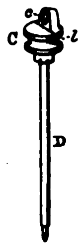
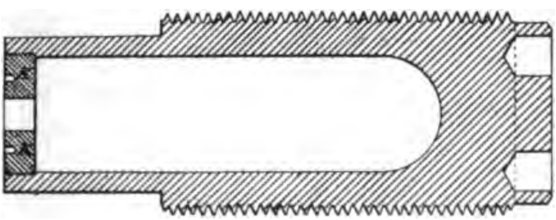
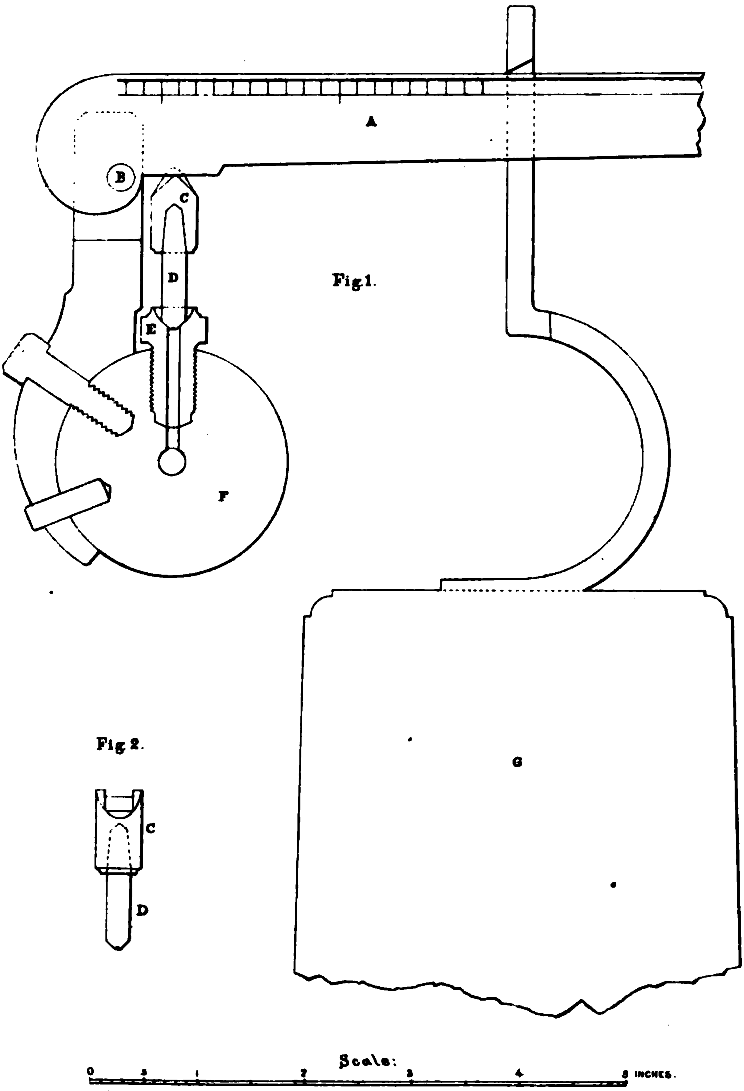


FIG. 6.



HOLLOW PLUG FOR RECEIVING THE PIEZOMETER
WHEN IN USE.


A
B
C
D
E
F
G
Fig.1.
Fig.2.
C
D
Scale:
0
½
1
2
3
4
5 INCHES.

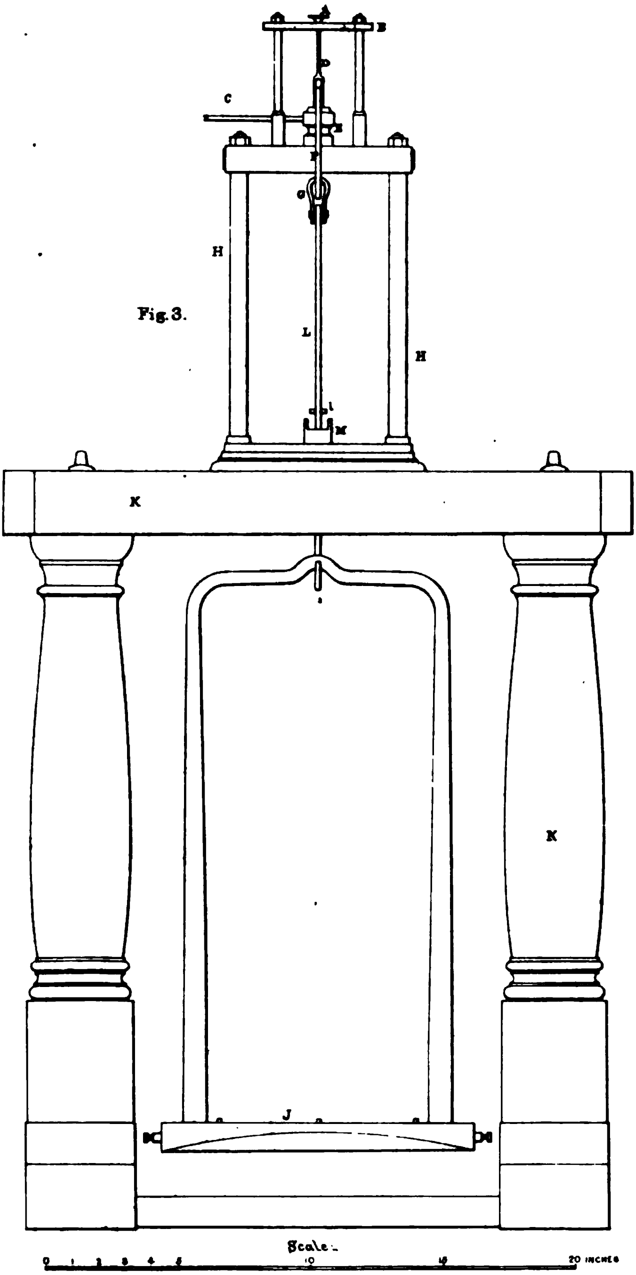


Fig. 3.

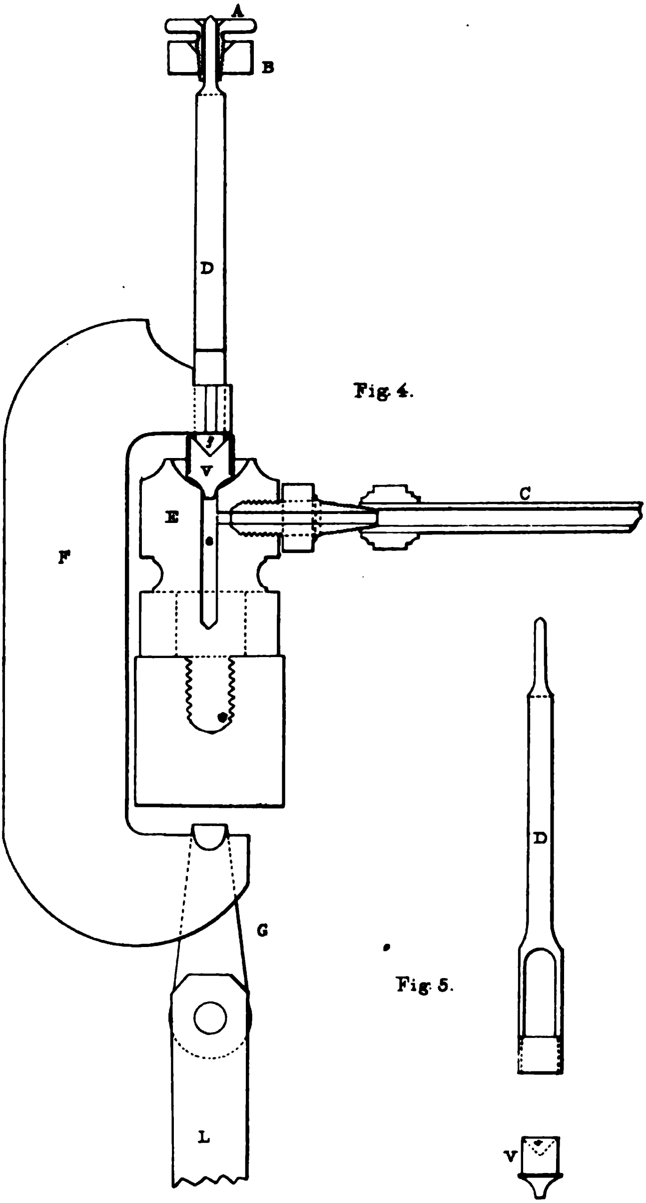


Fig. 4.

Fig. 5.

Fig. 6.

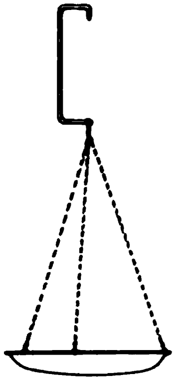


Fig. 10.

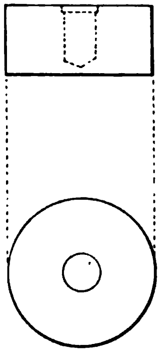


Fig. 9.

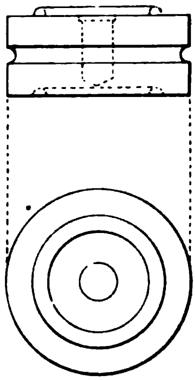


Fig. 7.

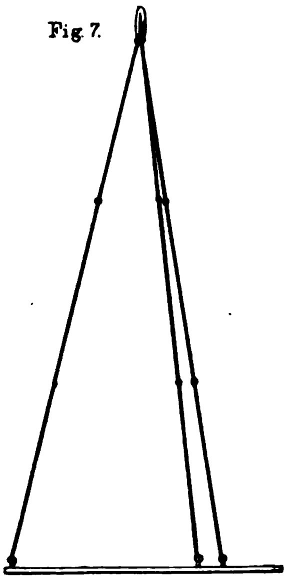


Fig. 8.

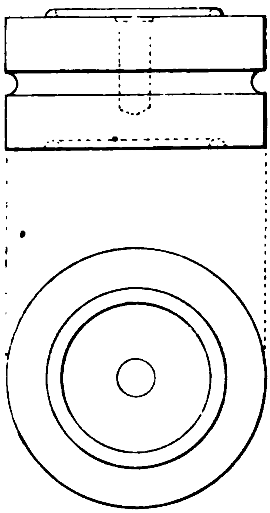


Fig. 12.

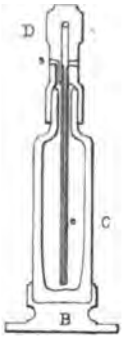


Fig. 13.

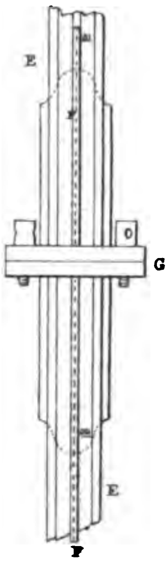


Fig. 14.

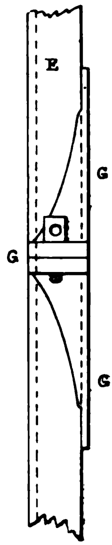
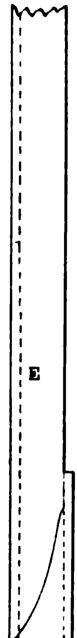


Fig. 11.



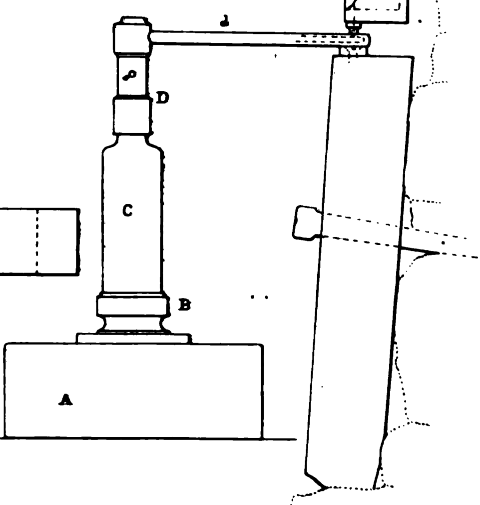


Fig. 15.

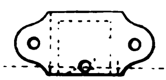
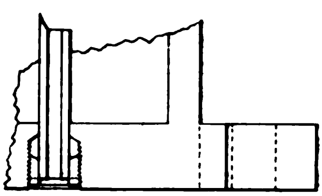


Fig. 16.



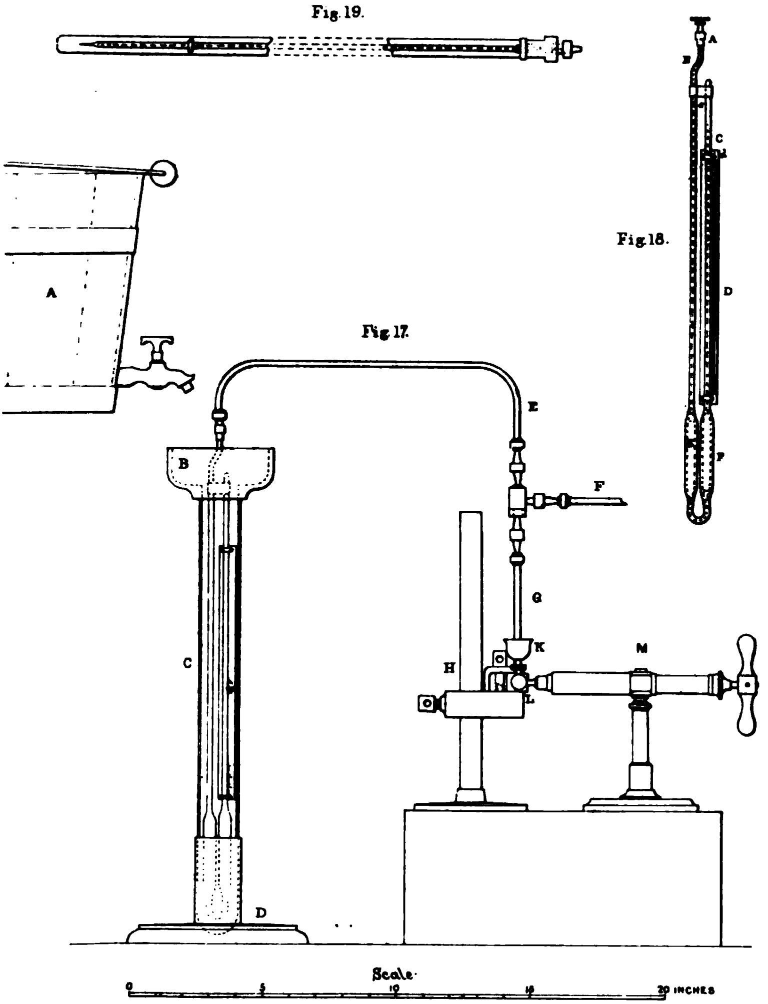


Fig. 19.
Fig. 18.
A
B
C
D
F
A
Fig. 17.
B
C
D
E
F
G
H
K
L
M
Scale
0
5
10
15
20 INCHES

Fig. 20.

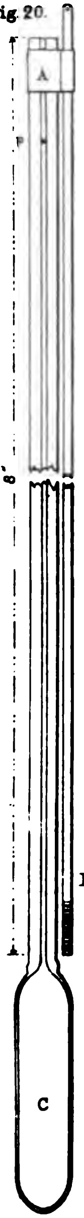


Fig. 21

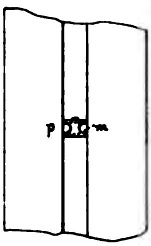


Fig. 22.

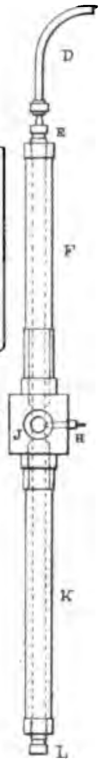


Fig. 26.

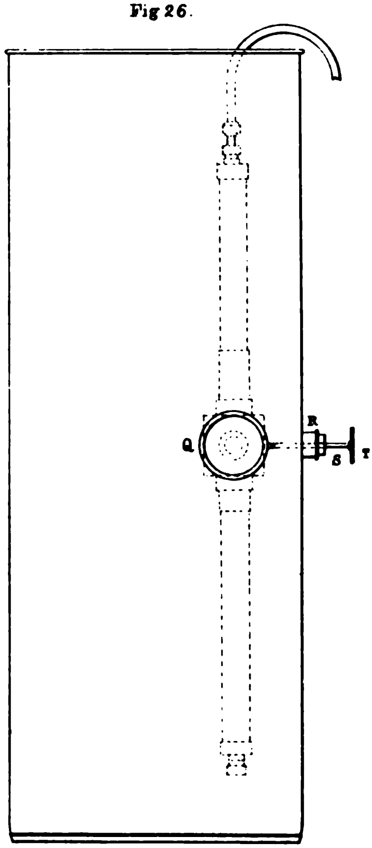


Fig. 23.

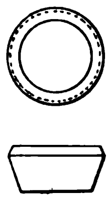


Fig. 25.

Fig. 24.

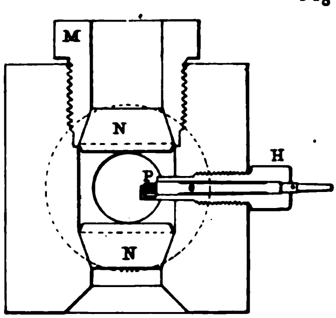


Fig. 27.

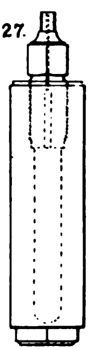
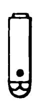
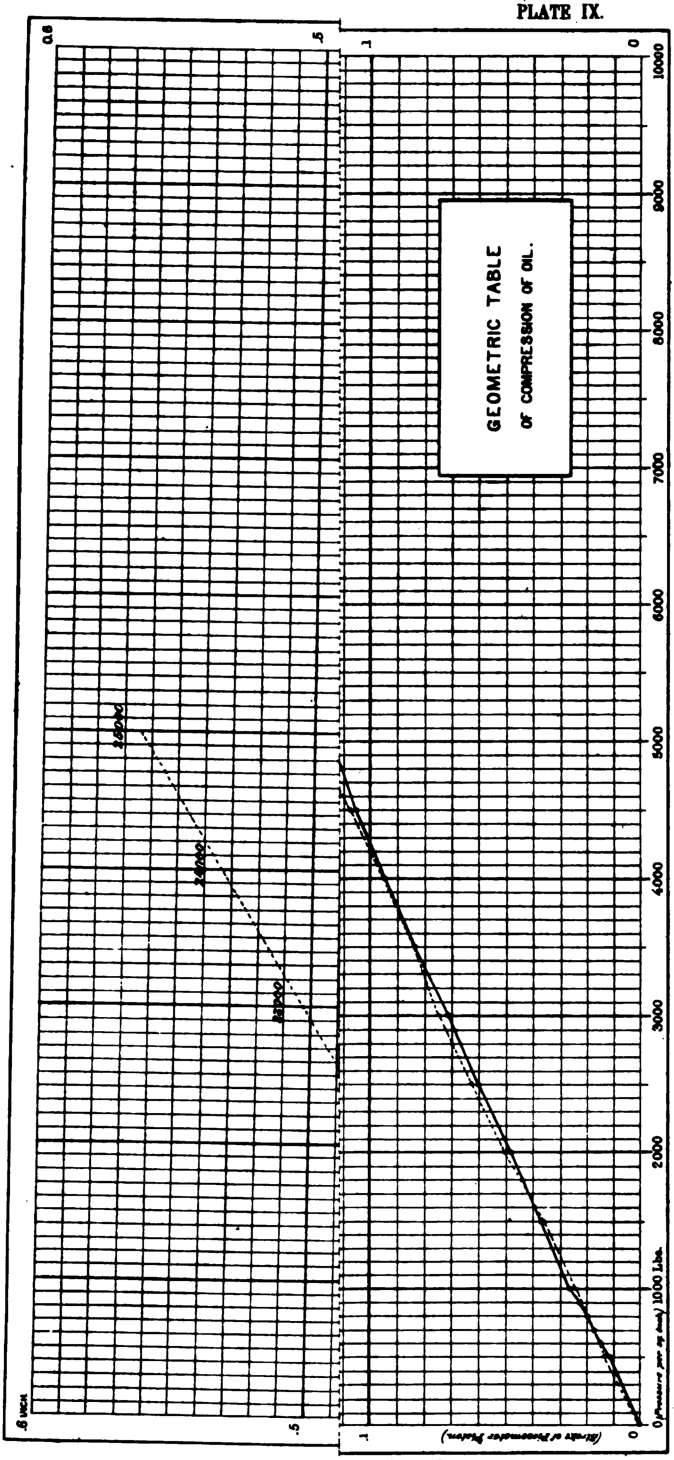
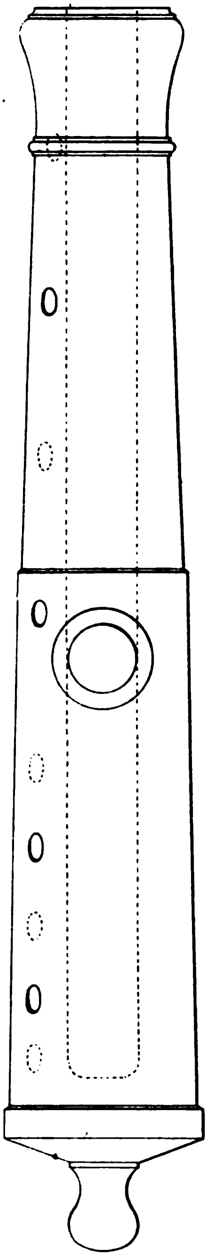


Fig. 28.

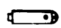




Appendix M.—Report of Chief of Ordnance, 1879.

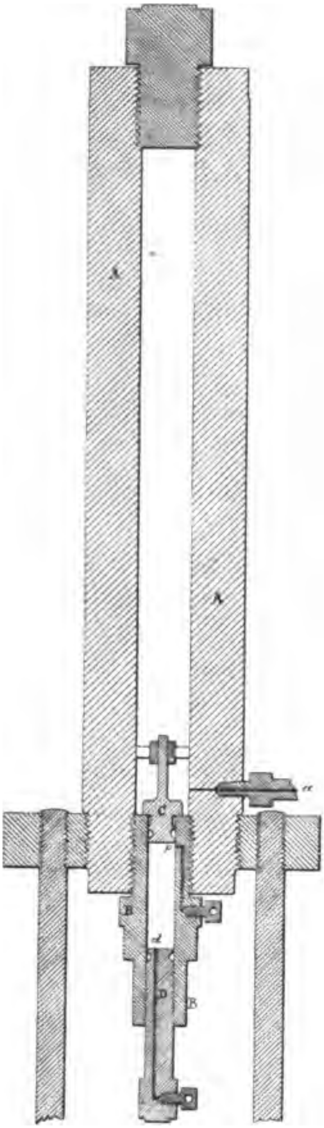


SKETCH OF BRONZE GUN, SHOWING INSERTION OF PIEZOMETER.

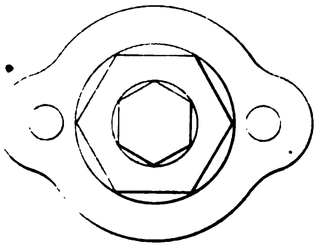


PIEZOMETER.

SECTION 4 IN. FROM BOTTOM OF BORE.



VERTICAL SECTION.



PLAN.

Piezometer.

APPENDIX N.

TRAJECTORIES OF ARMY REVOLVERS.

Capt. JOHN E. GREER, Ordnance Department.

(One plate.)

NATIONAL ARMORY, SPRINGFIELD, MASS.,
November 30, 1878.

SIR: In accordance with your instructions of November 8, I have the honor to submit herewith certain data in regard to the Colt's Army revolver.

As there were no records of firing at ranges greater than 25 yards on file at this armory, the results given are necessarily the mean of a limited number of targets specially made for the purpose of getting the data required. As these targets were made with great care by a most excellent marksman, Mr. R. T. Hare, of this armory, it is thought that the results obtained will not differ materially from those deducible from more extended firings.

It is also thought that as the Smith & Wesson revolver uses the same ammunition, (the service,) and as the velocities obtained are about the same as those obtained with the Colt, the data given may be considered, without material error, as applicable to the former revolver.

For these experiments the Colt's was sighted at 300 yards, the regular sight being nominally for 25 yards, but in reality just as much so for 50 yards.

THE COLT'S ARMY REVOLVER.

I.—RAPIDITY OF FIRE.

This arm may be fired 18 times in one minute and fifty-four seconds, beginning and ending with chambers empty.

II.—ACCURACY.

Deviations.	50 yards.	100 yards.	150 yards.	200 yards.	250 yards.	300 yards.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Mean horizontal	4.2	3.8	7	9.8	20	19.9
Mean vertical	3.3	7.4	10.1	12.5	14.8	20.7
Mean absolute	5.3	8.3	12.3	15.9	24.9	28.7

The above results are the average of a limited number of targets of 12 shots each.

III.—DRIFT.

The twist of the rifling being to the left, the drift is in the same direction. The tendency to throw the muzzle to the right by the pull on the trigger, serves, however, largely to neutralize the drift at ranges less than 150 yards. At 300 yards the drift is about 30 inches.

IV.—RECOIL.

Weight of revolver.	Weight of powder.	Weight of ball.	Recoil (theoretical).
2.31 pounds.	28 grains.	230 grains.	3.89 foot-pounds.

V.—PENETRATION IN WHITE PINE.

Range	50 yards.	100 yards.	150 yards.	200 yards.	250 yards.	300 yards.
Inches	$3\frac{3}{4}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$2\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{4}$

A penetration of one inch in white pine corresponds to a dangerous wound.

VI.—TRAJECTORY.

a.—Velocity.

Mean initial velocity, 730 feet.

b.—Angles of sight.

Range	50 yards.	100 yards.	150 yards.	200 yards.	250 yards.	300 yards.
Elevation						9′ 3″
Depression	1° 14′ 24″	57′ 13″	41′ 41″	25′ 5″	8′ 54″	

It is worthy of note that up to about 275 yards the axis of the bore is below the line of sight. This is probably due to the fact that before the ball has left the piece the barrel is rotated upward—the line of application of the force being above the point of resistance, the hand—until the axis of the bore is sufficiently far above the line sighted for the object to be struck. This is confirmed by firing the pistol with the *barrel* firmly clamped in a fixed rest.

With the revolver held in the usual manner in the hand, and with the 300-yards elevation, the center of impact was 44 inches above the center of the target at 50 yards. With the fixed rest the center of impact was, at the same distance and with the same elevation, $1\frac{1}{2}$ inches above the center of the target. The line of sight, 300-yards elevation, and axis of bore are nearly parallel; the latter result is, therefore, what was to be anticipated if the barrel were rigidly constrained.

With a rifle the use of a fixed rest invariably raises the height of the center of impact on the target, just the reverse of the pistol, but the circumstances of constraint are very different.

With the revolver the barrel was clamped, the cylinder and stock being entirely free, while with the rifle the stock is supported at the rear and sides, the barrel having a limited motion in and with the front of the stock.

c.—Ordinates of trajectory above line of sight. Range, 300 yards; 300-yards elevation.

Horizontal distance	50 yards.	100 yards.	150 yards.	200 yards.	250 yards.	300 yards.
Inches	43.7	69.4	79.7	71.5	47	0

As there is but one height of rear-sight on this revolver—viz, that corresponding to 50 yards—the center of impact will fall lower and lower on the target as the range is increased. It will, therefore, be necessary in firing to raise the line of sight as much above the object as the trajectory passes below it.

The following table gives the ordinates of points of the trajectory at 300 yards, below the line of sight corresponding to 50 yards.

d.—Ordinates of trajectory below line of sight. Regular sight; 50-yards elevation.

Horizontal distance	50 yards.	100 yards.	150 yards.	200 yards.	250 yards.	300 yards.
Inches	0	16.2	48.6	99.9	105.1	256.4

This table is important, as it shows how far above one should aim in order to hit the object at the distances given. For instance, at 150 yards the point aimed at should be about 4 feet, and at 200 yards 8 feet, above the object.

e.—Dangerous space.

CAVALRY AGAINST CAVALRY.

Distance.	Ascending branch of trajectory.	Descending branch of trajectory. Before the object.	Descending branch of trajectory. Beyond the object.	Maximum continuous dangerous space.	Total.
Yards.	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*
50	All.	All.	38.2	88.2	88.2
100	All.	All.	49.7	149.7	149.7
150	All.	All.	47.2	197.2	197.2
200	12	71.8	44.5	116.3	128.3
250	7.5	57.7	36.8	94.5	102.
300	5.3	41.7	31.2	72.9	78.2

CAVALRY AGAINST INFANTRY.

Distance.	Ascending branch of trajectory.	Descending branch of trajectory. Before the object.	Descending branch of trajectory. Beyond the object.	Maximum continuous dangerous space.	Total.
Yards.	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*
50	7.6	22.9	24.5	55.	55.
100		46.7	33.2	79.9	79.9
150		46.9	31.2	78.1	78.1
200		39.5	31.9	71.4	71.4
250		34.2	27.5	61.7	61.7
300		26.2	22.2	48.4	48.4

INFANTRY AGAINST CAVALRY.

Distance.	Ascending branch of trajectory.	Descending branch of trajectory.		Maximum continuous dangerous space.	Total.
		Before the object.	Beyond the object.		
Yards.	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*
50	All.	All.	63.5	113.5	113.5
100	All.	All.	64.2	164.2	164.2
150	All.	All.	57.5	207.5	207.5
200	All.	All.	50.5	250.5	250.5
250	51.2	72.	40.	112.	163.2
300	35.2	45.5	27.7	73.2	108.2

INFANTRY AGAINST INFANTRY.

Distance.	Ascending branch of trajectory.	Descending branch of trajectory.		Maximum continuous dangerous space.	Total.
		Before the object.	Beyond the object.		
Yards.	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*
50	All.	All.	35.	85.	85.
100	All.	All.	41.7	141.7	141.7
150	15	71.5	38.1	109.6	124.6
200	8.8	49.7	35.4	85.1	93.9
250	6	40.2	28.5	68.7	74.7
300	4.6	28.5	20.5	49.	53.6

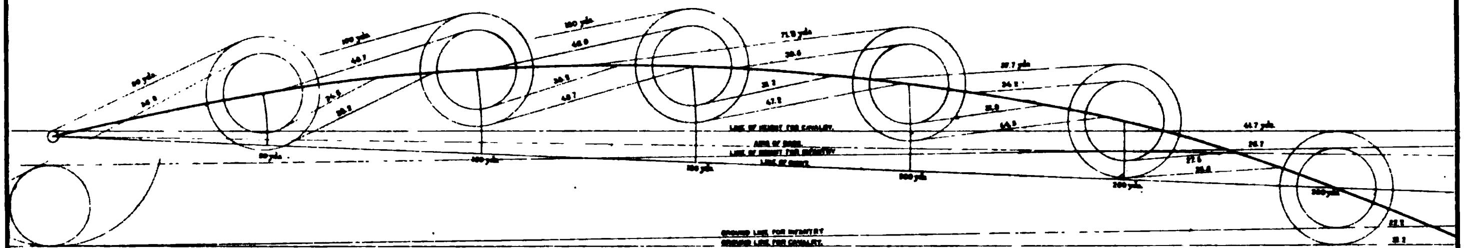
The dangerous space is determined under the assumption that a foot-soldier is 68 inches in height; that the head of a man on horse is 96 inches from the ground; that the pistol is at the height of the eye, or 4 inches below the top of the head, and that the points aimed at are 34 and 48 inches from the ground for infantry and cavalry, respectively.

The dangerous space may be increased by the firer lying down and aiming at the feet of the enemy.

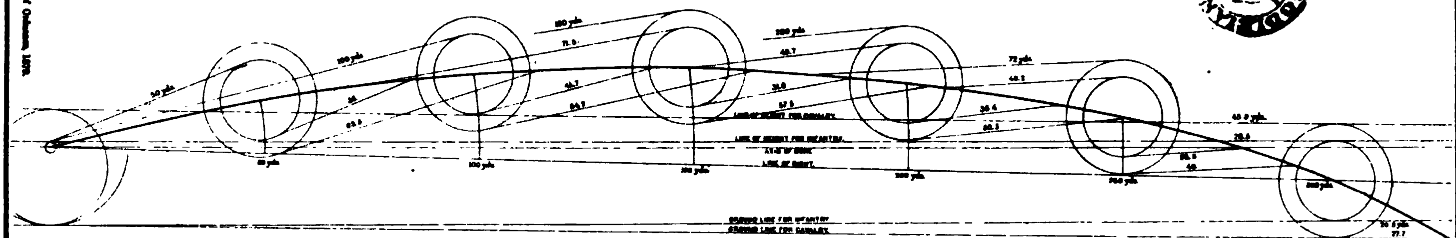
TRAJECTORY OF COLT'S REVOLVER.

Calibre 0.45.

Projected by the method of Polar Distortion. Horizontal Scale: Angles multiplied by 10.



Dangerous Spaces shown for Infantry and Cavalry, revolver being fired by mounted man, at ranges of 50, 100, 150, 200, 250 and 300 yds.
Height of Infantry assumed at 68 inches, that of Cavalry at 96 inches, and muzzle of revolver at height of eye, 92 inches.
Points aimed at, 34 and 48 inches from ground for Infantry and Cavalry respectively.



Dangerous Spaces shown for Infantry and Cavalry, revolver being fired by dismounted soldier, at ranges as above.
Muzzle of revolver at height of eye, 64 inches.

APPENDIX O.

TRAJECTORIES OF THE SPRINGFIELD AND THE PEABODY-MARTINI RIFLES.

Capt. JOHN E. GREER, Ordnance Department.

(One plate.)

Certain comparisons instituted between the Springfield and the Peabody-Martini rifles by Capt. John E. Greer, under the direction of Bvt. Col., James G. Benton, commanding the National Armory.

The Peabody was a new gun just received, together with a supply of ammunition, from the Providence Tool Company.

It was proposed to compare these rifles in the following particulars, viz: Accuracy at 300, 500, and 1,000 yards; penetration at 1,000 and 2,000 yards; flatness of trajectory, as shown by angles of elevation, at the same distances; initial velocity, and the effect of rifling on the velocity. Owing to the impossibility of getting a range of 2,000 yards, one of 1,669 yards—the longest that could be obtained—was taken. The results are contained in the following tables:

Accuracy.

Rifle.	300 yards.			500 yards.			1,000 yards.		
	Mean hor. dev'n.	Mean ver. dev'n.	Mean abs. dev'n.	Mean hor. dev'n.	Mean ver. dev'n.	Mean abs. dev'n.	Mean hor. dev'n.	Mean ver. dev'n.	Mean abs. dev'n.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Springfield	3	3.58	4.67	4.96	6.1	7.8	13.2	16.6	21.2
Peabody-Martini	4.5	2.76	5.28	8.3	8.8	12.1	21.3	31.4	37.94
	Target of 10 shots.			Target of 10 shots.			Target of 20 shots.		

Fired from shoulder and muzzle rest.

Penetration in white pine.

Rifle.	Weight of powder.	Weight of ball.	1,000 yards.	1,669 yards.
	Grains.	*Grains.*	*Inches.*	*Inches.*
Springfield	70	405	6	1.87
Peabody-Martini	85½	480	7.8	3.87

Angles of elevation.

Rifle.	1,000 yards.	1,669 yards.
	° ′ ″	° ′ ″
Springfield	2 59 4	6 39 55
Peabody-Martini	2 51 10	6 8 29

Velocities.

Rifle.	Weight of powder.	Weight of ball.	Velocities in feet.
	Grains.	*Grains.*	
Springfield	70	405	1312.2
Peabody-Martini	85½	480	1290.1

In order to ascertain the effect of rifling on the velocity, a Peabody-Martini, chambered for the United States service cartridge, was fired in comparison with the Springfield, the cartridges being taken from the same package.

The table shows a slight advantage in favor of the Springfield.

Velocities.—(To compare effect of rifling.)

Rifle.	Weight of powder.	Weight of ball.	Velocities in feet.
	Grains.	*Grains.*	
Springfield	70	405	1312.1
Peabody-Martini	70	405	1307.3

It should be stated that each velocity recorded in these tables is the mean of several taken on two machines—the Le Boulongé chronograph and the Benton electro-ballistic.

It should also be stated that with the Springfield not more than 10 rounds were fired at 1,669 yards before the target, 8′ by 12′, was hit 3 times, while with the Martini at least 60 rounds were fired to hit the target the same number of times.

Had the service cartridges used, which gave but 1,312 feet velocity, been up to the standard of 1350, the record with the Springfield would probably have been much more satisfactory

As it is, these results show superior accuracy on the part of the Springfield, accompanied with more power than is required to disable a man at ranges at which it is practically impossible for a marksman to hit so small an object. At ranges of 1,000 yards and upward, the trajectory of the Peabody is slightly flatter than the Springfield, but at shorter ranges*—those at which a rifle will ordinarily be fired in service—the trajectory of the Springfield is the flatter owing to its higher velocity. This velocity at long ranges of course falls off more rapidly than that of the Martini, due to the lesser weight of ball.

In order to determine the recoil 5 shots were fired from each gun, the recoil being measured by Captain Prince's dynamometer, initial comparison 50 lbs., and the mean taken.

Recoil.

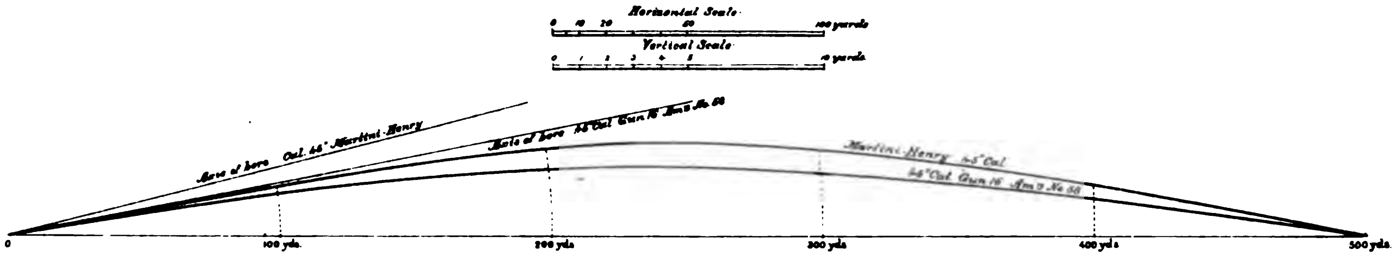
Rifle.	Weight of powder.	Weight of ball.	Recoil.
	Grains.	*Grains.*	*Pounds.*
Springfield	70	405	148
Peabody-Martini	85½	480	183

Accuracy at 1,000 yards.—(As recorded by Creedmoor system.)

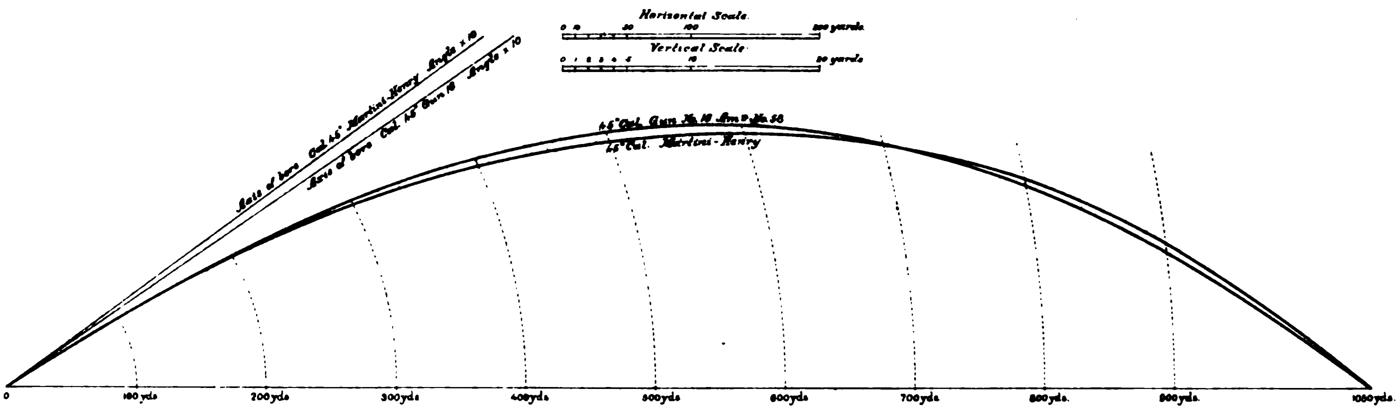
No. of shot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total.	Maximum.
Springfield	3	3	5	3	3	5	3	4	2	3	3	0	2	5	2	4	5	5	3	3	66	100
Peabody-Martini	5	2	0	0	0	5	5	5	0	0	3	0	3	3	3	4	3	3	0	0	44	100

*The appended trajectories, plotted by Capt. Wm. Prince, Ordnance Department, are taken from Ordnance Memoranda No. 15.

TRAJECTORIES OF SPRINGFIELD AND MARTINI RIFLES, CAL. .45, AT 500 YARDS



TRAJECTORIES OF SPRINGFIELD AND MARTINI RIFLES, CAL. .45, AT 1000 YARDS



APPENDIX P.

EXPERIMENTS WITH SMALL-ARMS.

Capt. JOHN E. GREER, Ordnance Department.

SPACE BETWEEN BULLET AND POWDER CHARGE.

In accordance with instructions to test the liability of a rifle-barrel to rupture, owing to the bullet not being entirely down to the powder charge, I have the honor to submit the following report:

In order to insert the bullets from the muzzle it was necessary to slightly reduce them in diameter.

The shells were loaded with the usual charge of 70 grains of powder, which was prevented from escaping from them by pasteboard wads, an open space of about half an inch still remaining.

Two shots were fired with the bullets just reaching the front of the shells, or 30 inches from the muzzle, and two at 25, 20, and 15 inches, respectively.

After each round the barrel was carefully examined; no signs of swelling or yielding in any manner were visible.

The pressures as indicated by the pressure-plug are given in the following table:

Distance from muzzle.	30 inches.	25 inches.	20 inches.	15 inches.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Pressure per square inch	17,750 16,250	9,000 6,500	5,500 5,250	4,100 4,000
Mean	17,000	7,750	5,375	4,050

The pressures obtained with the bullet crimped in the shell in the regular manner were about 27,000 pounds.

It would seem, therefore, from these results, that instead of an air-space between powder and bullet being a source of danger to the barrel the bore is relieved from strain, owing to the larger space in which the powder gas is permitted to expand.

Velocities were next taken with the bullet crimped in the shell, just down to the shell, and 5 inches in advance of the last position, or 25 inches from the muzzle, with the following results:

Velocities.

Number of shot.	Bullet crimped in shell as in service cartridge.	Bullet 30 inches from muzzle, or just down to shell.	Bullet 25 inches from muzzle.
1	1390.6	1321.5	1170.1
2	1368.1	1311.2	1010.4
3	1382.8	1332.8	1027.1
4	1371.0	1346.5	1031.0
5	1371.0	1307.8	1031.0
Mean	1376.7	1323.9	1053.9

In order to ascertain the effect on accuracy of fire, of allowing a slight air-space between the powder and ball, two targets of ten shots each were made at 300 and also at 500 yards with the bullets just down to the shells, or 30 inches from the muzzle. These bullets were inserted from the rear, and were not reduced in size. The following is the record:

Accuracy.

300 YARDS.

First target.	Center of impact.		Second target.	Center of impact.	
	B. 2".1	R. 7".8		B. 3".6	R. 5".2
	Inches.			*Inches.*	
Mean vertical deviation	5.6		Mean vertical deviation	5.9	
Mean horizontal deviation	5.8		Mean horizontal deviation	3.6	
Mean absolute deviation	8.0		Mean absolute deviation	6.9	

500 YARDS.

First target.	Center of impact.		Second target.	Center of impact.	
	B. 1".1	R. 3".2		B. 3"	R. 3".8
	Inches.			*Inches.*	
Mean vertical deviation	7.3		Mean vertical deviation	8.4	
Mean horizontal deviation	11.2		Mean horizontal deviation	8.6	
Mean absolute deviation	12.5		Mean absolute deviation	12.0	

The accuracy, it will be seen, is fairly satisfactory, though not quite so good as that ordinarily obtained with the regular cartridges. The effect, then, of placing the bullet just down to the shell is to reduce the pressure from about 27,000 pounds to 17,000, and the velocity from 1,376.7 feet to 1,323.9 without materially diminishing the accuracy. While it would be impracticable in service to use such a method of loading, it is thought these results may possibly point the way to a completed cartridge in which an air-space exists, the velocity being brought to the proper standard by varying the charge of powder, and which will cause much less strain on the barrel than the service cartridge. This could be readily determined by taking any gun chambered for a long-range cartridge and using lighter charges than that necessary to fill the shells. In other words, the air-space should be in the shell and the bullet should be crimped in the usual way. The chief expense necessary to such a trial would be in chambering a gun and the pressure-plug block for the longer shells.

EFFECT OF CONTINUED RAPID FIRING ON THE RIFLE.

While firing a large number of cartridges recently, testing firing-pins, the opportunity was presented of complying with instructions to ascertain the effect of continued rapid firing on the piece, so far as its capability of being handled was concerned.

Mr. A. Cranston, of this armory, was selected, as having great experience with this gun, to fire it the requisite number of times.

Two hundred rounds were fired by him in 12 minutes, or at the rate of about 17 per minute.

This was accomplished without once removing the left hand, which held the piece, from the stock or changing its position. The barrel became heated sufficiently to burn the hand after 20 or 30 rounds, but there is no need to touch it in firing.

So far as the heat of the stock was concerned the piece could easily have been fired many more rounds, but the operator became fatigued holding the arm off-hand and firing the time stated.

The piece, after being thoroughly cooled, was placed in the rest in the proving room. Two hundred and forty cartridges were then fired in 10 minutes, or at a rate of 24 per minute. The front of the stock appeared to be burning, and it was thought best to discontinue the firing. On examination, however, it was found that it was rubber burning on the barrel, the rubber having been melted from that which surrounds the muzzle in the rest. The piece was handled freely, and it could have been fired at least 100 rounds more by being careful to keep the fingers from the barrel.

After 25 rounds fired rapidly, with aim, the barrel would burn the hands if held tightly.

RIFLE SIGHTS AND POWDER.

In accordance with instructions, I have the honor to submit the following report on the various sights proposed for the Springfield rifle, and also on the powder employed in the preparation of cartridges used in connection therewith.

Three sights were furnished me for trial and comparison, viz: the service model 1878, the "buckhorn," recently adopted, and one proposed to be placed on the tang by Lieut. Col. J. C. Kelton, Adjutant-General's Department.

Targets were made by Mr. R. T. Hare at distances of 300 and 500 yards, with service cartridges manufactured at Frankford Arsenal, July, 1878—which have given better accuracy than any others received from there in a long period, and cartridges prepared at this armory with Hazard's F. G. or Kentucky rifle powder.

The following table shows that the buckhorn sight gave better results at both ranges and with both kinds of cartridges than the other two; also, that the best accuracy was obtained with this sight when used in connection with the F. G. cartridges.

300 YARDS.

Sights.	Cartridges.	Center of impact.				Deviations.		
		A.	B.	R.	L.	M. V	M. H.	M. A.
Tang	July, 1878		7.2	4.6	......	5.24	2.88	5.98
Buckhorn	do	3.3	......	.2	......	2.9	3.76	4.75
Regular	do	19.7	.....	......	5.9	4.1	3.88	5.65
Tang	F. G	....	11.3	......	2.1	3.1	2.32	3.87
Buckhorn	do	2.6	......	......	1.7	3.12	1.84	3.62
Regular	do	17.9	......	......	3.2	4.72	2.6	5.39

500 YARDS.

Sights.	Cartridges.	Center of impact.				Deviations.		
		A.	B.	R.	L.	M. V.	M. H.	M. A.
Tang	July cartridges	4.7		34.4		9.24	6.32	11.2
Buckhorn	do	8.6		26.7		7.52	3.84	8.44
Regular	do	3.09		27.		8.3	4.8	9.59
Tang	F. G. cartridges		1.3	22.5		4.76	6.9	8.38
Buckhorn	do	10.7		16.9		5.98	3.9	7.14
Regular	do	29.5		16.7		4.1	7.9	8.9

In order to ascertain whether the combination of buckhorn sight and F. G. cartridges would maintain its superiority in the hands of different marksmen, the members of the Armory Club, six in number, were required to fire the buckhorn and tang sights with both kinds of cartridges at 200 and 500 yards.

The score was kept according to the Creedmoor system.

It will be seen by inspection of the table that both sights gave better results with the F. G. than with the service cartridges; also, that the buckhorn gave the best accuracy in all cases except the last. This falling off was due, it is thought, to a shifting of the slide along the leaf by the recoil, owing to the weakness of the springs.

This defect has been corrected by knurling the edges of the sight-base

200 YARDS.

Sights.	Cartridges.	Maximum.	Percentage of maximum.
Tang	Frankford, July, 1878	210	80.95
Buckhorn	do	210	82.86
Tang	F. G. prepared	210	83.3
Buckhorn	do	210	83.8

500 YARDS.

Sights.	Cartridges.	Maximum.	Percentage of maximum.
Tang	Frankford, July, 1878	170	72.94
Buckhorn	do	200	83.
Tang	F. G. prepared	210	83.3
Buckhorn	do	210	80.95

It has been found after many trials that an extremely high velocity is not consistent with the best accuracy with the Springfield rifle. The standard is 1,350, though of course there are frequent variations above and below. The velocity given by the July cartridges was found to be but 1,312 feet, and the excellent targets made with them go far to show that a standard of perhaps 1,325 feet would be the most suitable for service.

The Kentucky rifle-powder gives 1,340 feet. This powder is of more uniform grain than the service and costs about 3 cents more per pound.

APPENDIX Q.

ACTION OF SEA-WATER ON BRASS CARTRIDGES.

Capt. JOHN E. GREER, Ordnance Department.

EXAMINATION OF BRASS CARTRIDGE SHELLS TAKEN FROM THE WRECKED STEAMSHIP JOHN BRAMALL.

These shells were under water about ten days, and after their recovery remained on the wharf about fifteen days before inspection.

About 200 cases, containing nearly 275,000 unloaded shells, were opened and samples taken from each. Both exterior and interior of the shells were coated with verdigris, or, more strictly, the oxychloride of copper, the whole being in a wet and dirty condition.

Of 23 shells brought to this armory only three had the fulminate uninjured, or so slightly as not to prevent explosion. In the others the fulminate of mercury had been reduced, and the free mercury had amalgamated the anvil, head, and primer of the shell, rendering all these parts extremely brittle, and so much deteriorated as to well deserve the term rotten.

Ten of these shells I reprimed and loaded with 85 grains Hazard musket-powder, and fired them in a Peabody-Martini. Five of them split through the head, two of them in eight or ten places. In order to drive off the damaged primers—no tool for the purpose being at hand—I filled the shells with water. I then inserted a bullet in the mouth of each, and tapped on it with a hammer, forcing off the primer by hydraulic pressure. Three or four burst in the head, though scarcely any pressure was required—not enough indeed to swell out the shell or change its form in any particular. The remaining shells I cleaned and laid aside to see what further effect time would have upon them. The metal of these shells appeared extremely brittle at the head. When crushed in a vise the heads cracked in many places, while new shells of the same lot would fold tightly over without rupture. The action of the salt water had also been to eat away the metal around the primers, causing a liberal escape of gas at every round. I have since witnessed a trial of shells taken from the same lot at the Winchester Repeating Arms Company's Works. Five packages of five shells each were taken, the old primers removed, reprimed, and loaded with the proof charge required by the Turkish inspectors. This charge is the regular one of 85 grains, but is of No. 4 powder (American), or of the grade ordinarily known as rifle-powder. The conditions of inspection, so far as relates to the proof, are that from each lot of 50,000 shells 200 shall be fired with the charge mentioned. Should two shells fail, or 1 per cent., 200 more are taken, and if one fails, or one-half of 1 per cent., the whole lot is rejected. As these shells had been accepted, the inference is that, before their immersion in the salt water, they were strong enough to sustain the proof. Of the 25 shells taken, one was found cracked, and one was retained by Mr. Bennett, secretary of the company, for examination under a microscope. Of the 23 fired, 9 burst, 4 dangerously; that is, with an escape of gas that would have seriously injured the eyes and hands of the firer. With the hope of removing the mercury, it was proposed to

heat the heads of the shells and volatilize it, if possible. Bloxam, in his text-book on metals, gives the boiling point of mercury, at which it freely distils, at 662°, though it is sensibly volatile at temperatures above 68° or 70°. He also gives the boiling point of zinc at which volatization freely takes place, at a bright red heat, estimated at 1904°. With this range of temperature between the volatility of the two metals it would seem possible to drive off the mercury. Fownes, in his chemistry, confirms the statements given above, but he also adds, page 319, what is extremely pertinent to the case in point, "that the volatility of mercury at the boiling point is singularly retarded by even minute quantities of lead or zinc." Here the zinc is thoroughly amalgamated, and to drive off the mercury in the open air a heat is required which approximates the heat required to volatilize the zinc itself, the latter fusing at 770°, but little beyond the boiling point of mercury when no zinc is present. This heat also anneals the shell, rendering the anvil so soft as to be incapable of supporting the primer against the blow of the firing-pin, with consequent miss-fire. In addition, the metal would probably set out more like copper, making it difficult to extract the shell except with such guns as the Springfield, having a lever power to operate the extractor, or bolt guns, having a cam to start the bolt during its unlocking. The latter point, however, was not determined, owing to the limited number of shells at my command. Having been rendered soft by the annealing, these shells would also be unable to resist disfiguring by the rough usage they receive in service.

Had these shells been of copper, or nearly so, like the United States service, which, it is understood, contain but 5 per cent. of zinc., the amalgamation, it is thought, would hardly have taken place. It is true that all metals ordinarily used in commerce can be amalgamated, with the exception of iron and platinum. Copper and some other metals, however, offer such resistance, that the amalgamation is, to a large extent, surface only. Under these circumstances it would seem that the department has acted wisely in selecting copper as the standard cartridge metal, especially when it is well known that loaded brass shells rapidly deteriorate from the action of the powder. In fact, it was the knowledge of this deterioration that induced the Turkish Government to purchase unloaded shells and balls with the view of putting them in store.

With regard to patched ammunition, it again would seem that the action of the department has been wise in rejecting its use.

During the investigation of these shells Mr. Hobbs, of the Union Metallic Cartridge Company, exhibited some loaded cartridges taken from the wreck of the steamship Guatemala a few years since. These had patched bullets. The patch, by capillary attraction, transferred the moisture from without to the powder within; and though the cartridges were several times carefully cleaned on the outside, corrosion continued to take place from within. Never being entirely freed from moisture, the action between the shell and ball continued, causing the latter to oxidize and exfoliate in a manner which would have seriously leaded the rifling, with consequent falling off in accuracy of fire. In the matter of accuracy, the service bullets, when properly lubricated, give better results than the patched. The advantage claimed for the patch is absence of leading of grooves; but with the service bullet, with suitable lubricant, no leading of any moment is found to occur.

The patch is liable to become roughed up and mutilated, giving bad results; and even when in perfect condition, stripping is of frequent occurrence.

This was noticed in recent trials with the Springfield and Peabody-Martini rifles, when the accuracy of the Springfield was better at all ranges than the Martini with its patched ammunition. At ranges of nearly 1,700 yards the Martini balls sometimes fell two or three hundred yards short of the target, striking the water, and at others passed way beyond it. It is thought these results were due to irregular action of the patches.

APPENDIX R.

REPORT ON MANUFACTURE OF LIFE-SAVING GUNS.

Lieut. C. W. WHIPPLE, Ordnance Department.

(Seven plates.)

WEST POINT FOUNDERY,
Cold Spring, *N. Y.*, *March* 10, 1879.

On the 12th of last September a contract was awarded the West Point Foundery for the construction of two hundred 2.5-inch bronze guns, designed by Lieut. D. A. Lyle, Ordnance Department, for the United States Life-Saving Service, and a period of four months was allowed for its completion. As the resident inspector at this foundery, I was first directed to supervise the construction of these guns, and finally to inspect them; and I have the honor to submit the following description of the various incidental operations:

The West Point Foundery had had no experience in the manufacture of bronze guns, except that derived from casting a few, at long intervals, for yachts. The contract prescribed * * "that the guns shall be made of bronze, the composition to consist of 90 per cent. of Lake Superior ingot copper and 10 per cent. of Banca ingot tin. It is further stipulated that no scrap metal, such as zinc, old copper, or old bronze shall be used in the fabrication. It is stipulated that the guns shall be cast in iron chills; diameter of chills at breech 6½ inches; diameter of chills at muzzle 5½ inches; sinking-head at least 18 inches high. One bronze specimen for testing, as per drawing attached, to be furnished for each gun. The tensile strength and other physical properties shall be subject to the approval of the inspecting officer. Diameter of finished bore to be two and five-tenths (2.5) to two and five hundred and five thousandths (2.505) inches." * * *

Plate I is a copy of the drawing which accompanied the contract.

The South Boston Foundery had, not long before, made a few guns for the same purpose. Lieutenant Lyle's report on the subject had not yet been published, but it was understood here that one difficulty encountered was the presence of minute filiform cracks, which covered the surface of the casting and necessitated the excess of metal (0.5-inch) required by the contract. In fact, this was supposed to be the only, though a very serious, obstacle to be overcome. Any means which would prevent the formation of these cracks would prevent the necessity of the extra metal, and save considerable time in finishing. It was thought this might be secured by casting the guns under pressure; and with this object in view, more than any expectation of improving the physical qualities of the alloy, a special mold (Plate III) was made, to be presently described. As a precaution, however, another mold was made similar in size and shape to that used at the South Boston Foundery, except that was designed with the intention of casting with the breech down, in order to save labor in finishing. The details of this mold as first made are shown in Fig. 1, Plate II, and the description of

its construction is so similar to that given by Lieutenant Lyle (page 219, Report of Chief of Ordnance, 1878) that it will not be necessary to repeat it. The thickness of the chill, however, was 2.5 inches instead of 1.75 inches, and there was no sand-head.*

Chill-mold No. 3 (Plate III) was similar in its general features to No. 1 (Plate II). It was, however, 0.5 inch smaller in interior diameter, and was arranged for a length of sinking-head of 11 inches instead of 18 inches. The mouth of the mold was closed by a cast-iron plate 2.5 inch thick, bolted to the upper horizontal flange of the chill. A hole was bored through the axis of this plate to allow the admission of the metal and of a small steel plunger 5 inches long by 4 inches diameter. Two iron uprights, secured at bottom to the iron bed-plate, supported above the mold a 30-ton hydraulic jack.

Mold No. 1, completed first, was first used, and three guns were cast of inferior metal, simply for the purpose of educating the molders.

Six guns were then cast, using the prescribed metals. The details of the operations as conducted differ from those described by Lieutenant Lyle principally in the fact that the tin was melted in a separate crucible, and that its mixture with the copper, which was poured on top of it, took place in the pouring-ladles.

To summarize these details:

1. *Heating the chill-mold.*—No convenient furnace being on hand, this was accomplished by building a wood fire about the chill, which was inclosed in an iron cage. A special furnace was ultimately built for the purpose.

2. *The furnaces.*—Three pots were used for the copper, each containing one crucible. The tin was melted in two crucibles, introduced into the same pot.

3. *Charging the crucibles.*—The metals were placed in the crucibles, and after being weighed the tin was removed.

4. *Melting.*—The fires were lighted before the crucibles were introduced. When the copper was fairly melted, the crucibles containing the tin were placed in the pot. When melted, the tin was poured into two heated pouring-ladles, to each of which was added the charge of copper contained in one crucible, the mass being stirred with an iron rod. The charge of the third crucible (the hottest being retained for the purpose) was finally divided between the two ladles.

5. *Casting.*—The ladles were then poured in succession into the runner-box as rapidly as possible, the surface of the running metal being skimmed with a wooden scraper.†

6. *Cooling.*—With gun No. 1 the mold was placed, during casting, in a barrel, which was filled with running water, in the hope of preventing the expansion of the chill. As a consequence the chill cracked. With guns Nos. 2 and 3 water was poured freely on the chill after casting. With Nos. 4 and 5 less water was used, and with No. 6 and following, none was used at all.

The results obtained with these six guns are contained in the annexed table. The specimens were taken from the lower part of the sinking-head, and the dimensions, shown in Fig. 1, Plate V, were the same as of

* These preparations for casting were commenced by the West Point Foundery upon notification that the contract had been awarded them, and were completed before the receipt of the articles of agreement.

† Subsequently the pouring-ladle was made self-skimming.

those taken from the guns made at the South Boston Foundery and tested by Mr. C. B. Richards.

Number of gun.	Weight of copper, Lake Superior, (Quincy).	Weight of heads.	Weight of tin (Banca).	Total weight of charge.	Per cent. of copper.	Per cent. of tin.	Specific gravity.	Tensile strength.	Extension per inch at rupture.
	Lbs.	Lbs.	Lbs.	Lbs.				Lbs.	
1	270	....	28	298	90.6	9.4	8.494	34,996	0".105
2	270	....	28	298	90.6	9.4	....	23,900	0".03
3	270	....	28	298	90.6	9.4	Condemned	for cavities as	soon as cast.
4	240	30	25	295	90.5	9.5	8.2764	26,457	0".04
5	240	30	25	295	90.5	9.5	Condemned	for cavities as	soon as cast.
6	240	30	25	295	90.5	9.5	8.4357	29,957	0".049

The appearance of the fracture of each specimen indicated loose, coarse texture, and imperfect mixture of the metals. All of these guns were at once condemned.

Gun No. 7 was then cast under pressure as follows: While the metal was in the crucibles the chill and the plunger were raised to a dull heat. As soon as the metal was ready to pour, the mold was lowered into its pit and adjusted on the bed-plate so as to be directly under the press. When the metal reached the level of the hole in the upper plate the runner-box was removed, and the plunger, picked up by tongs, quickly fitted to the hole. Two men then pumped the jack down as far as the quickly hardening metal would permit. Eight guns were ultimately cast under pressure with results as shown in following table.

Number of gun.	Weight of copper.	Weight of bronze.* Heads.	Weight of bronze.* Chips.	Weight of tin.	Time of melting copper.	Time from mixing metals to casting.	Depth to which plunger sinks.	Length of time between pouring and removing casting.	Specific gravity.	Tenacity.	Extension per inch at rupture.	Appearance of fracture.
	Lbs.	Lbs.	Lbs.	Lbs.	H.	M.	Inches.	Hrs.		Lbs.	Inch.	
7	128	90	8	14.5	......	......	....	......	8,5535	44,099	0.153	Very fine close texture, thoroughly mixed.
11	132.5	90	12	15	3	5	3½	1¾	8,5812	31,984	0.054	Rather coarse, well mixed, but excess of tin.
12	185	73	11	18.5	3	7	Failed to work.	......	8,5847	33,189	0.09	Rather coarse and poorly mixed.
13	128	128	4	12.75	2½	20	3	......	8,5815	38,205	0.156	Close and well mixed.
14	158	100	7	15.75	3¼	20	2½	......	8,6836	47,311	0.287	Very fine, close, and well mixed.
15	158	103	8	15.75	1½	10	3	20	8,7174	40,170	0.152	Close and well mixed.
16	158	79	15⅞	15⅞	2⅛	30	Failed to work.	35	8,6741	37,537	0.106	Rather close and tolerably well mixed.
18	192	121	3	21¼	1⅝	15	...do ...	45	8,6303	35,671	0.144	Rather coarse, fairly mixed, but tinny.

Guns 8, 9, and 10 had in the mean time been cast without pressure. Up to No. 10 every gun, except No. 7, had been condemned either as imperfect castings, or for low tenacity, low density, or poor mixture of the metals. Fortunately, Mr. Davis, superintendent of the ordnance

* "Heads" is used to designate metal taken from the body of condemned castings and from the main part of sinking-heads; "chips," that metal which works its way into the joints of the mold during casting, and the very upper part of sinking-heads.

shops at the Washington navy-yard, who had had much experience in the manufacture of bronze guns, was present at this time, and suggestions were asked from him in regard to improving the character of the castings. These suggestions were as follows:

1. The guns should be cast breech up, for the purpose of increasing the diameter and consequent weight of the sinking-head.
2. The tin should be melted by simply adding it at the proper time to the copper in the crucibles; not melted separately.
3. No pouring-ladle should be used, but the crucibles emptied simultaneously into the mold, pouring rapidly until the mold was filled to the trunnions, and afterwards more slowly.

He had never seen pressure applied to a casting and ventured no opinion on it. He disapproved of heating the chill beyond merely warming it, or cooling it by water after casting, and ultimately recommended increasing the length of the sinking-head by the addition of a sand-head, the diameter of which should be greater than the diameter of the rest of the sinking-head.

His suggestion as to reversing the position of the mold so as to cast with the breech up was never attempted, but in casting No. 12 his recommendations were carried out to the extent of adding the tin to the copper in the crucibles, but the contents were mixed in the pouring-ladle. An attempt to apply pressure to this gun was unsuccessful, as the plunger jammed from being improperly centered.

Nos. 13, 14, 15, and 16 were cast under pressure and according to his suggestions, except that the mold was in each case hotter than desired.

No. 17 was cast in mold No. 2, which had been increased 12 inches in length by the addition of a sand-head (Plate IV). This mold also differed from No. 1 in that the interior diameter at chase was 5 inches instead of 5.5 inches.

No. 18 was the last gun cast under pressure, the operation and results being too irregular to warrant further experiment.

No. 19 was cast in the same mold as No. 17, and in this and all subsequent castings an attempt was made to follow uniformly the operations as conducted in gun No. 17. Two molds were used, alternating with each other. (Chill No. 2, Plate IV.)

From the fact that the upper parts of sinking-heads and the "chips" which were formed by the joints of the mold were known to contain a greater percentage of tin than the body of a casting, all parts of a sinking-head, after being cut from a casting, and all condemned guns* were broken into small pieces and arranged into "classes," according to their respective distances from the surface of the sinking-head. It was assumed that the upper parts of sinking-head, and "chips," contained 13

*The constitution of the alloy changes, not only in the cooling but in the melting, by the continual reduction of the quantity of tin, which oxidates much faster than the copper, though the latter be present in so much greater mass. Dussausoy found that gun metal, having the proportions of 100 copper and 11 tin by weight, had the following constitutions after each of six consecutive meltings, indicating the rapidity with which oxidation of the tin occurs:

RESULTING CONSTITUTION OF ALLOY.

Fusions.	Copper.	Tin.
1	100.3	10.7
2	100.7	10.3
3	101.8	9.2
4	103.0	8.0
5	104.0	7.0
6	105.5	5.5

Vide Mallet, Const. of Art'y, p. 87.

per cent. of tin, and the remainder the same as the body of the gun—10 per cent., less amount lost by oxidation, &c.

This loss from oxidation was disregarded, since the allowance of 13 per cent. of tin to the upper parts of sinking-head was probably slightly in excess of the true amount.*

In making up the charges of "bronze" to be added to a casting a certain percentage was taken from each "class."

The contract specified that a specimen from the sinking-head of each gun should be subjected to mechanical tests, and the dimensions of the specimens were prescribed by an attached drawing (Fig. 1, Plate V). It was particularly desirable that this standard as regards dimensions should have been maintained, in order to properly compare the results with those obtained in the very careful experiments of Mr. C. B. Richards, at the Colt's manufactory.

In testing specimens from 1 to 12 (excepting No. 7) the fracture took place close to the upper shoulder, and the surface of the specimens showed no indication of being elsewhere strained at all.

To ascertain to what extent the portions of the specimen more remote from the surface of the sinking-head shared the weakness exhibited at the shoulder, two specimens were taken from each sinking-head of several castings, one turned as prescribed, and the other preserving the total length of specimen, but diminishing the distance between shoulders to 3 inches by extending the upper shoulder toward the center of the specimen. (Plate V, Fig. 2.) This would oblige the fracture to occur in a part of the specimen more nearly assimilating to the character of the metal in the gun.

The difference in results was so marked that it seemed unjust to require the foundery to abide by an agreement which, perhaps, unjustly was condemning gun after gun. This idea was strengthened by the following experiments:

1. The sinking-head having been sufficiently increased in length, two specimens were taken from the head of No. 22, the one directly above the other, and while the upper gave a tenacity of 43,286, the lower gave 46,335.

2. Gun No. 21 was condemned on a tenacity obtained from the sinking-head of 34,555; but a specimen taken afterward from the breech gave a tenacity of 43,286. Another fact considered was that the specimens tested by Mr. Richards were taken from guns cast with the breech up, whose sinking-heads were consequently of greater size and density than those here. The machine in use here for testing was so arranged that the first strain which could be recorded was about 10,000 pounds to the square inch. Consequently, no delay occurring up to that point, the specimen was quickly subjected to this strain, and, crude appliances rendering very nice work impracticable, was probably broken in less than a quarter of the time occupied by Mr. Richards in attaining the same end. This alone would account for very decided differences in tenacity and extension, and render comparison between the two results unsatisfactory. Consequently I recommended to Lieutenant Lyle that the foundery be allowed to change the shape of the specimens. [Inconvenience was then found in consequence of the extension, which was frequently so great as to necessitate the lowering of the beam during the operation.]

Guns were being cast at the rate of six and seven a day, and none could be touched until specimens from their sinking-heads had been

* *Vide* Mallet, p. 94.

broken and the density determined. One-half of the time allowed by the contract had been expended, and, to save time, permission was consequently given to reduce the total length of specimens to 4 inches, preserving 3 inches between shoulders. All specimens after No. 46 were turned to these dimensions.

Gun No. 17 and all following (except No. 18, cast under pressure) were cast with a sand-head, whose interior diameter was larger than that of the body of the gun, for the purpose of securing for the sinking-head a large amount of metal which might remain a considerable time in a liquid state. While the sinking-head was inclosed, together with the rest of the casting, in the chill-mold, it hardened with the same rapidity as the rest, and to a great extent failed to perform the important function of supplying to the body of the gun the metal required to replace the shrinkage.

An attempt was made to secure accuracy in the weight of the two ingredients of the alloy, but in consequence of an inability to personally superintend the operation and the haste with which the work was prosecuted the success was but partial.

Comparing guns Nos. 25 and 26, both were apparently treated alike, and the molder, aware of the good results obtained with a specimen from No. 25, expected equally good from No. 26. Upon investigation it was found that the "heads" added to the charge for No. 26 came solely from the upper parts of different heads in which the percentage of tin was considerably greater than the mixture called for.

	Pounds.	Copper.	Tin.
The mixture used for gun No. 25 was ...	161 copper .... =	161	
	151 heads (10 per cent. tin) =	135.9	15.1
	5 chips (13 per cent. tin) =	4.3	0.7
	18 tin .... =	0.0	18.0
Total weight	335	301.2	33.8
The mixture used for gun No. 26 was ...	152 copper .... =	152	
	153 heads (10 per cent. tin) =	137.7	15.3
	4 chips (13 per cent. tin) =	3.48	0.52
	17 tin .... =	0.00	17.00
Total weight	326	293.18	32.82
But under the supposition that the "heads" contained 13 per cent. tin the proportions became		152	
		133.11	19.89
		3.48	0.52
		0.	17.00
Total		288.59	37.41

making the mixture contain 11½ per cent. tin. The appearance of the fracture of the specimen as well as the low tenacity had suggested at once that the percentage of tin was too great; and in gun No. 44 the same peculiarities led to an investigation which ultimately disclosed the fact that a double charge had accidentally been added to the copper, in spite of the presence of an attendant specially employed to watch every process in the casting.

Guns Nos. 177 and 178 were condemned because an unknown brand of tin had been used, which was discovered in the same way as the defects in Nos. 26 and 44.

Although Banca tin* was prescribed by the contract, a brand of English tin ("the Lamb and Flag") was allowed to be used to a great extent, both because it had been recommended by Mr. Davis as the tin almost exclusively used by the Navy in their gun constructions, and because at times Banca tin could not be obtained in the quantities and at the time required.

In Lieutenant Lyle's report of the fabrication of his experimental guns at South Boston he speaks (Report Chief of Ordnance for 1878, p. 221) of castings condemned on account of defective trunnions. The same difficulty was met with here, and was similarly remedied by cutting away the metal in the chill so as to increase the size of the trunnions in the casting. Before this, however, guns Nos. 27, 31, and 35 had been condemned at an early stage of fabrication for this defect, and when the first lot were offered for final inspection many more of the guns among those first cast suffered a like fate. To save these guns, which were otherwise satisfactory, P., K. & Co. asked authority to "burn on" new trunnions, a process which consisted simply in replacing the imperfect portions of the trunnions with new metal. Before granting permission the following experiment was tried, for the purpose of testing the intimacy of union between the old and new metals which the process could guarantee: A cylinder 3 inches long and 1.5-inch diameter, cut from the sinking-head of one of the guns, had new metal burned on to it until its length was doubled. The cylinder was then turned down to the shape of an ordinary specimen, in such manner as to leave the joint between the two metals at a distance of 1 inch from the shoulder. It was then broken in the machine. The fracture took place in the old metal, and at a distance of about 1 inch from the point of union. The specimen stood about 40,000 pounds to the square inch, and the surface, after fracture, presented a curious appearance. (Plate V, Fig. 4.) The old or original metal showed the ordinary blistered, flattened appearance exhibited by good bronze under such circumstances, but the surface of the new metal was scarred and striated in the direction of its length, and resembled more a piece of tough wrought iron after strain.

Permission was then given to try the experiment on guns Nos. 27, 31, and 35 (which had not yet received their powder proof), which was conducted as follows:

The imperfect portion of one trunnion was turned off in a lathe so as to leave as much metal as possible untouched in the vicinity of the rimbases. It was rarely necessary to turn off more than one-tenth of an inch, except at times, from the face of the trunnion. The gun was then buried in sand, the axis of the trunnions vertical, the trunnion to be

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*The purest tin in the market comes from the islands of Banca and Billotin, in the Malayan archipelago, and is sold once or twice a year at Amsterdam and Rotterdam. In Whitney's *Metallic Wealth of the United States*, published in 1854, is given the following analysis of Banca tin:

Tin	99.961
Iron	.019
Lead	.014
Copper	.006
	100.000

English "refined" tin, from the Cornish mines, stands next as regards purity, and is followed by, 1st. English tin (which includes "Lamb and Flag;) 2d. Straits tin, from the Malayan peninsula; 3d. Australian tin.

The following are some of the prominent brands of Lake Superior copper, a preference being given to the first two: "Minnesota," "Quincy," "Central," "Calumet and Hecla," "Copper Falls."

repaired uppermost. A mold was then formed in the sand about and above this trunnion and slightly larger than it in diameter. (Plate II, Fig. 2.) A ladle of melted bronze was then poured very slowly into the mold, which, soon overflowing, ran into a receptacle prepared for it in the vicinity. The molten metal gradually melted that portion of the casting with which it came in contact, and when this fact was assured (by feeling the face of the trunnion with an iron rod) the pouring was stopped. In a few minutes the gun was taken from the sand and transferred to the trunnion lathe. But one trunnion was prepared for this process at a time, in order to have the assistance of one finished trunnion in centering the other for turning. After being repaired, these three guns were subjected to the usual firing proof, and having stood it satisfactorily, all other guns possessing this but no other defect were similarly repaired.

PROOF.

According to the contract each gun was to be "proved by firing three rounds, the proof-charge to be 12 ounces Hazard's Navy cannon-powder, * * * and a cylindrical bolt or projectile to weigh not less than 18 pounds; * * * the powder proof to be applied with 'rough boring' before 'finishing reaming,' diameter of rough bore to be from 2.25 inches to 2.3 inches; one gun from the first lot finished to be put to extreme proof by continuous firing with heavy charges."

Guns Nos. 7, 10, and 14 were fired as prescribed, mounted upon a carriage which was made to recoil up a sand slope. The effects on these guns were somewhat disastrous. They were excessively enlarged both on the interior and exterior, and the trunnions were badly bent. Upon consultation with Lieutenant Lyle it was agreed that, since 8 ounces would be the maximum service-charge for the guns under ordinary circumstances, the proof-charge could be diminished to that amount. As an additional precaution the carriage was lightened so as to reduce it in weight to 86 pounds, and two trunnion rings or sleeves (first made of bronze, afterwards of steel) were made to slip over the trunnions to prevent them from being bruised during the proof firing. Three small pins were subsequently attached to the outer surface of the sleeves, which, fitting into a groove cut in the trunnion bed-plate, prevented any outward motion. When first used these rings occasionally slipped outward slightly after the first fire, and, being unobserved, the strain at the next fire was thrown on a point of the trunnions removed from the rimbases and the trunnions consequently bent slightly to the front. Excepting this mishap, no effect was produced upon any gun during proof after the 8-ounce charge had been adopted.

It has been stated that the contract required one gun of the lot first finished to be subjected to extreme proof. Gun No. 18 had been originally condemned on account of the weakness of the metal, as shown by the specimen from the sinking-head, although the appearance of the fracture showed (what most of the early guns lacked) a fair mixture of the metals. By accident this gun was offered for and subjected to proof, after which it was discovered that it had been condemned. An offer was made to P., K. & Co. and accepted, that this gun should be finished for extreme proof, with the understanding that if it failed they were to replace it and stand the expenses of its proof.

Firing record of gun No. 18, subjected to extreme proof.

Number of rounds.	Weight of charge.	Weight of projectile.	Remarks.
	Oz.	*Lbs.*	
3	8	18.5	First proof, no noticeable effect. (Gun bored to 2.3 inches.)
200	8	18.5	Greatest enlargement of bore (midway between vent and trunnions) 0.0115 inch, approximate. Greatest enlargement of bore at muzzle, 0.001 inch. Enlargement of first reinforce 3.5 inches; in front of vent 0.0115 inch. Vent unscrewed and found to be in perfect condition. Enlargement of chase at muzzle 0.005 inch.
10	9	18.5	Enlargement of first reinforce 0.022 inch. Enlargement of chase 0.0115 inch.
10	10	18.5	Enlargement of first reinforce 0.05 inch, point of greatest enlargement moving toward trunnions. Enlargement of chase 0.022 inch, point of greatest enlargement midway between face and trunnions.
10	11	18.5	Enlargement of first reinforce 0.065 inch. Enlargement of chase 0.050 inch.
10	12	18.5	Enlargement of first reinforce 0.080 inch. Enlargement of chase 0.060 inch.
10	13	18.5	Enlargement of first reinforce 0.102 inch. Enlargement of chase 0.0663 inch.
10	14	18.5	Enlargement of first reinforce 0.106 inch. Enlargement of chase 0.068 inch.
10	15	18.5	Enlargement of first reinforce 0.121 inch. Enlargement of chase 0.099 inch.
10	16	18.5	Enlargement of first reinforce 0.121 inch. Enlargement of chase 0.101 inch.
10	17	18.5	Enlargement of first reinforce 0.129 inch. Enlargement of chase 0.112 inch.
10	18	18.5	Enlargement of first reinforce 0.138 inch. Enlargement of chase 0.120 inch.
303	......	......	

After commencing to fire with 13 ounces the trunnions were found to be slightly bent to the front, and after the third round a slight fracture was observed in rear of the trunnions and at their junction with the rimbases. This was a natural consequence of the bending of the trunnions, and as they bent the more to the front (for which an overtaxed carriage was greatly responsible), the more, but to a slight extent, the fracture extended.

After completing the 10 rounds with 15 ounces the axis of the trunnions was found to be at its face out of its true position 0.18 inch. Toward the close of the proof, gas escaped about the vent piece.

Three hundred and three rounds had now been fired from gun No. 18, and it was considered that its endurance was sufficiently proved. It was therefore placed in a lathe and first cut into two parts through a plane perpendicular to the axis of the gun and in front of the vent, and the forward part afterward cut into two parts through a plane at right angles to the axis of the trunnions. Serious defects were found to exist in the shape of holes extending from the bore toward either trunnion, two of which were about 0.5 inch deep. It can only be surmised that, as this gun was cast under pressure, the cinder, which under ordinary circumstances of casting has a tendency to rise to the surface, may have been retained in the gun, more especially as the means used for skimming the metal was, when this gun was made, very imperfect.

Plate VI shows the ultimate enlargement of this gun, and, for the sake of comparison, of gun No. 7, both cast under pressure, after proof-firing with three rounds with 12 ounces of powder. To an extent it corroborates the opinion, entertained at the time it was suggested changing the proof-charge from 12 to 8 ounces, that the more moderate charge would the better enable the gun to subsequently stand the heavier.

INSPECTION.

All principal dimensions were verified by specially constructed gauges, and proved the work to have been performed with great care.

The workmen had been provided with a 2.5-inch Whitworth gauge, which they tried in the bore of every gun before it left the boring-lathe; nevertheless the bores of about one-tenth of all guns, when offered for inspection, were found to be slightly small and had to be re-bored. This was due to the fact that the gauge had occasionally been tried in the guns while still warm, and consequently enlarged, from the effect of the boring tool.

TABLES.

Table No. 1 contains the records of mechanical tests of specimens taken from the sinking-heads of guns Nos. 239 and 227. The situation of the former in the sinking-head is shown in Fig. 5, Plate V. Specimens 4 and 5 were taken from positions in No. 227, corresponding to C and A of same plate. Nos. 6 and 7 were radial specimens from the same head.

Number of gun.	Number of specimen.	Length.		Diameter.		Specific gravity.	Tensile strength per square inch.	Elastic limit.	Extension per inch at rupture.	Hardness.	Reduction of diameter at point of rupture.	Original area.	Area after rupture.	Remarks.
		Original between shoulders.	After rupture.	Original.	After rupture.									
		Inches.	*Inches.*	*Inches.*	*Inches.*		*Lbs.*	*Lbs.*	*Inches.*		*Inches.*	*Sq. inches.*	*Sq. inches.*	
239	1	3.000	4.661	0.559	0.390	8.7912	49,000	16,000	0.562	5.06	0.169	0.24542	0.11945	See C, fig. 5, plate. Tested by Lieut. C. S. Smith, at United States ordnance agency.
239	2	3.000	4.094	0.801	0.699	....	49,731	....	0.364	......	0.102	0.50391	0.38474	See B, fig. 5, plate. Tested at West Point foundery.
239	3	3.000	4.392	0.803	0.662	8.8387	35,289	....	0.461	......	0.141	0.50643	0.34419	See A, fig. 5, plate. Tested at West Point foundery.
227	4	3.006	4.285	0.559	0.445	....	48,000	19,000	0.428	4.57	0.114	0.24542	0.15553	Tested by Lieut. C. S. Smith, at United States ordnance agency.
227	5	3.000	3.465	0.799	0.740	8.6639	39,898	....	0.155	......	0.059	0.5014	0.43008	Tested at West Point foundery.
227	6	3.000	3.444	0.800	0.748	....	36,208	....	0.648	......	0.052	0.50625	0.43943	Radial specimen. Tested at West Point foundery.
227	7	3.000	3.186	0.800	0.780	....	27,255	....	0.062	......	0.020	0.50625	0.47783	Radial specimen. Tested at West Point foundery.

All specimens were taken as near as possible to the surface of the casting.

Manufacture of 2.5-inch bronze guns at the West Point foundery, 1878.

Castings.			Metal used.								Time.			Test of samples.			Remarks.
Date.	Foundery number.	Register number.	Weight of copper.	Brand of copper.	Bronze. Heads.	Bronze. Chips.	Weight of tin.	Brand of tin.	Per cent. of tin.	Total weight.	Melting copper.	From adding tin to casting.	Between pouring and removing casting.	Specific gravity.	Tenacity.	Extension per inch at rupture.	
			Lbs.		*Lbs.*	*Lbs.*	*Lbs.*			*Lbs.*	*H. M.*	*M.*	*H. M.*		*Lbs.*	*Inches.*	
Oct. 16	1	......	270	Quincy....	......	......	28	Banca...	9.4	298	....	....	....	8.494	34,996	0.105	Condemned. Chill heated, then surrounded by running water during casting; chill cracked.
Oct. 16	2	......	270	....do	......	......	28	...do	9.4	298	....	....	....	....	23,900	0.03	Condemned. Chill heated; water thrown upon it after casting.
Oct. 16	3	......	270	....do	......	......	28	...do	9.4	298	....	....	....	....	....	....	Condemned on account of cavities. Chill cooled as preceding.
Oct. 18	4	......	240	....do	30	......	25	...do	9.5	295	....	....	....	8.2764	26,457	0.04	Condemned. Chill cooled as preceding, but less water used.
Oct. 18	5	......	240	....do	30	......	25	...do	9.5	295	....	....	....	....	....	....	Condemned on account of cavities. Chill cooled as preceding.
Oct. 18	6	......	240	....do	30	......	25	...do	9.5	295	....	....	....	8.4357	29,957	0.049	Condemned. Chill cooled without water.
Oct. 19	7	200	128	....do	90	8	14½	...do	10.2	240.5	....	....	....	8.5535	44,099	0.153	Cast under pressure.
Oct. 21	8	......	131	....do	96	8	14¾	...do	10.1	249.75	....	....	....	8.6586	35,720	0.068	Condemned.
Oct. 21	9	......	131	....do	90	5	14¾	...do	10.1	240.75	....	....	....	8.7674	37,227	0.069	Condemned.
Oct. 21	10	91	97	....do	118	12	11	...do	10.2	238	....	....	....	8.5028	37,134	....	
Oct. 25	11	......	132½	....do	90	12	15	...do	10.3	249.5	3 0	5	1 45	8.5812	31,984	0.054	Condemned. Cast under pressure.
Oct. 25	12	......	185	....do	73	11	18½	...do	9.5	287.5	3 0	7	....	8.5847	33,189	0.09	Condemned. Cast under pressure.
Oct. 26	13	32	128	....do	128	4	12¾	...do	9.6	272.75	2 30	20	....	8.5815	38,205	0.156	Cast under pressure.
Oct. 26	14	15	158	....do	100	7	15¾	...do	9.5	280.75	3 15	20	....	8.6836	47,311	0.287	Cast under pressure.
Oct. 28	15	......	158	....do	103	8	15¾	...do	9.5	284.75	1 35	10	20	8.7174	40,170	0.152	Condemned for cavities detected in boring. Cast under pressure.
Oct. 28	16	14	158	....do	79	15⅞	15⅞	...do	9.6	268.75	2 10	30	35	8.6741	37,537	0.106	Cast under pressure.
Oct. 29	17	2	224	....do	80	20	24⅞	...do	10.2	348.88	2 30	15	40	8.8103	53,314	0.328	Mold lengthened 12 inches by addition of sand head.
Oct. 30	18	......	192	....do	121	3	21¼	...do	10	337.25	1 50	15	45	8.6303	35,671	0.144	Condemned. Subject to extreme proof. Cast under pressure.
Oct. 30	19	152	143	....do	141	4	15¾	...do	10	303.75	1 50	18	1 10	8.8047	44,207	0.149	
Oct. 30	20	34	201	....do	90	3	22	...do	9.9	316	2 30	15	35	8.7649	43,729	0.151	
Oct. 31	21	......	160	....do	107	15	17¾	...do	10.2	299.75	1 10	18	40	8.6117	34,555	0.07	Condemned. Specimen taken from breech, s. g., 8.7304; tenacity, 43,286; extension, 0″.2.
Oct. 31	22	95	213	....do	100	16	23¼	...do	10.3	352.25	1 10	15	45	8.7681	46,335	0.212	

Manufacture of 2.5-inch bronze guns at the West Point foundery, 1878—Continued.

Castings.			Metal used.								Time.			Test of samples.			Remarks.
Date.	Foundery number.	Register number.	Weight of copper.	Brand of copper.	Bronze. Heads.	Bronze. Chips.	Weight of tin.	Brand of tin.	Per cent. of tin.	Total weight.	Melting copper.	From adding tin to casting.	Between pouring and removing casting.	Specific gravity.	Tenacity.	Extension per inch at rupture.	
			Lbs.		*Lbs.*	*Lbs.*	*Lbs.*			*Lbs.*	*H. M.*	*M.*	*H. M.*		*Lbs.*	*Inches.*	
Nov. 1	23	143	185	Quincy....	115	7	20½	Banca...	10	327.5	1 15	15	40	8.8130	44,771	0.172	
Nov. 1	24	27	200	....do.....	90	4	22	..do....	9.9	325	2 0	12	1 0	8.7989	40,980	0.248	
Nov. 1	25	......	161	....do.....	151	5	18	..do....	10.8	355	1 20	14	45	8.8116	52,330	0.20	Condemned, after proof, for defects in gun.
Nov. 1	26	198	152	....do.....	153	4	17	....	10	326	1 45	15	30	8.659	39,393	0.123	The bronze "heads" used should really have been classed chips, giving 11.5 per cent. tin.
Nov. 2	27	176	199	....do.....	138	5	14	Banca...	8	356	1 45	16	35	8.8366	51,350	0.38	
Nov. 2	28	41	168	....do.....	157	4	16½	..do....	9.5	340.25	....	12	40	8.7580	44,253	0.215	
Nov. 2	29	......	177	....do.....	154	5	17¾	..do....	9.6	368.75	1 40	20	45	8.7972	50,406	0.260	Condemned after proof, for defects in body of gun.
Nov. 4	30	166	190	....do.....	129	4	20	..do....	9.5	352	1 20	15	40	8.6965	42,651	0.137	New chill.
Nov. 4	31	178	215	....do.....	100	3	21½	..do....	9.4	339.5	1 30	15	35	8.8215	51,795	0.32	
Nov. 4	32	182	222	....do.....	110	2	21¾	..do....	9.2	355.25		15	35	8.6780	43,686	0.18	
Nov. 4	33	180	217	....do.....	93	4	21¾	..do....	9.4	335.75	....	16	40	8.8280	53,184	0.30	
Nov. 4	34	122	206	....do.....	85	3	22	..do....	9.8	316	1 20	15	30	8.7830	46,990	0.25	
Nov. 4	35	......	225	....do.....	70	2	22½	..do....	9.3	319.5	1 10	12	35	8.8196	53,960	0.48	Condemned after proof, for defects in body of gun.
Nov. 5	36	94	217	....do.....	130	3	21½	L. & F...	9.5	371.5	1 40	15	35	8.8226	50,154	0.345	
Nov. 5	37	173	211	....do.....	127	4	20	..do....	9.2	362	1 10	12	35	8.8120	48,980	0.207	
Nov. 5	38	43	261	....do.....	71	3	26	..do....	9.3	361	1 20	12	35	8.7876	50,332	0.344	
Nov. 5	39	149	318	....do.....	......	2	35½	..do....	10	355.5	1 5	15	35	8.8055	46,369	0.41	
Nov. 5	40	43	326	....do.....	......	3	36¼	..do....	10	365.25	1 30	12	25	8.8868	54,806	0.429	
Nov. 5	41	119	210	....do.....	105	......	23¼	..do....	9.9	338.25	1	12	30	8.72	56,727	0.41	
Nov. 6	42	84	198	....do.....	105	4	19¼	..do....	9.6	321.75	1 10	15	35	8.8124	51,809	0.319	
Nov. 6	43	40	204	....do.....	105	......	20¼	..do....	9.4	329.25	1 10	12	30	8.8386	46,254	0.19	
Nov. 6	44	......	194	....do.....	105	......	39½	..do....	14.3	338	1 15	10	35	8.5551	34,246	0.079	Condemned. Double charge found to have been accidentally added.
Nov. 6	45	120	188	....do.....	115	3	18¾	..do....	9.5	324.75	1 10	8	28	8.7877	51,084	0.319	
Nov. 6	46	64	197	....do.....	107	2	19¾	..do....	9.4	325.75	55	10	30	8.7717	42,361	0.181	
Nov. 6	47	184	192	....do.....	111	3	19¼	..do....	9.5	325.25	1 5	8	35	8.8183	52,656	0.328	
Nov. 7	48	58	195	....do.....	114	2	19½	..do....	9.5	330.5	1	6	28	8.7280	39,097	0.135	
Nov. 7	49	121	196	....do.....	109	4	19½	..do....	9.4	328.5	1 10	8	35	8.7766	52,460	0.339	

Nov.	7	50	......	194	....do	116	4	19½	...do	9.4	333.25	1	15	8	35	8.6277	42,573	0.246	Condemned after proof, for hole in chase.
Nov.	7	51	79	195	....do	114	3	19½	...do	9.5	331.5	1	10	8	30	8.7651	48,247	0.293	
Nov.	7	52	30	186	....do	117	2	18½	...do	9.4	323.5	....	....	....	35	8.6279	53,969	0.309	
Nov.	7	53	75	189	....do	115	3	19	...do	9.5	306	1	15	10	30	8.7954	49,413	0.309	
Nov.	8	54	77	172	....do	100	4	17¾	...do	9.6	298.75	1	5	8	35	8.7691	46,359	0.298	
Nov.	8	55	47	175	....do	102	3	17½	...do	9.5	307.5	1	10	10	30	8.7813	44,294	0.258	
Nov.	8	56	46	178	....do	119	3	17¾	...do	9.5	312.25	1	15	15	35	8.5964	45,440	0.338	
Nov.	8	57	......	174	....do	108	2	17¾	...do	9.4	301.25	1	15	12	35	......	......	......	Condemned. Imperfect casting.
Nov.	8	58	62	179	....do	118	2	18	...do	9.5	312	1		16	35	8.7181	40,469	0.179	
Nov.	8	59	......	177	....do	114	3	17¾	...do	9.5	311.75	1	5	10	30	8.3621	35,169	0.154	Condemned.
Nov.	9	60	81	178	....do	114	4	17¾	...do	9.5	318.75		45	14	30	8.4383	41,850	0.151	
Nov.	9	61	18	177	....do	110	3	17¾	...do	9.5	307.75	1	5	10	25	8.5344	38,117	0.204	
Nov.	9	62	35	175	....do	108	2	17½	...do	9.4	302.5	1		10	35	8.5461	38,307	0.164	
Nov.	9	63	......	175	....do	115	4	17½	...do	9.5	311.5	1	5	10	30	8.6241	40,771	0.181	Condemned. Imperfect casting.
Nov.	9	64	52	173	....do	113	3	17¾	...do	9.4	306.25	1	5	12	28	8.7802	45,444	0.220	
Nov.	9	65	38	176	....do	108	2	17½	...do ...	9.4	303.5	1	15	10	25	8.7406	43,152	0.201	
Nov.	11	66	......	178	....do	108	......	17¾	Banca...	9.4	301.5	1	15	10	30	7.6244	33,029	0.216	Condemned after proof. Cavity in bore of gun.
Nov.	11	67	26	167	....do	112	......	16¾	...do	9.4	295.75	1	15	10	35	8.7538	44,601	0.246	
Nov.	11	68	......	175	....do	110	......	17½	...do	9.4	302.5	1		10	30	8.5284	41,653	0.256	Condemned. Imperfect casting.
Nov.	11	69	89	176	....do	107	3	17½	...do	9.4	303.5	......	......	10	35	8.8338	50,762	0.324	
Nov.	11	70	......	192	....do	96	......	19¼	...do	9.3	307.1	1		15	45	8.8004	39,198	0.153	Condemned after proof. Defects in chase.
Nov.	11	71	17	196	....do	91	2	19½	...do	9.3	308.5	1	10	....	40	8.7714	44,686	0.218	
Nov.	12	72	......	176	....do	107	......	17¾	...do	9.4	300.75	1	15	15	30	......	......	......	Condemned. Imperfect casting; honey-combed on each side along longitudinal joint of chill.
Nov.	12	73	......	189	....do	106	......	19	...do	9.4	314	1	15	15	35	......	......	......	Condemned. Imperfect casting; honey-combed on each side along longitudinal joint of chill.
Nov.	12	74	......	185	....do	107	......	18½	...do	9.4	310.5	1	5	10	30	......	......	......	Condemned. Imperfect casting; honey-combed on each side along longitudinal joint of chill.
Nov.	12	75	100	188	....do	104	3	18¾	...do	9.4	313.75	1	10	15	35	8.7225	45,470	0.307	Small cracks had formed in chill, more especially where two sections united. These were hammered smooth before this casting.
Nov.	12	76	......	190	....do	105	......	19	...do	9.4	314	1	15	15	35	8.7389	43,225	0.212	Condemned. Imperfect casting.
Nov.	12	77	28	180	....do	105	......	18	...do	9.4	308	......	......	....	35	8.5545	41,158	0.182	
Nov.	12	78	......	177	....do	109	3	17½	...do	9.4	306.5	......	......	....	35	8.5601	42,361	0.250	Condemned. Imperfect casting.
Nov.	12	79	......	191	....do	110	......	19	L. & F...	9.4	320	1		10	30	8.4839	39,295	0.203	Condemned after proof. Defect in body.
Nov.	13	80	29	191	....do	110	3	19	...do	9.4	323	1	10	15	35	8.7095	50,154	0.363	
Nov.	13	81	56	181	....do	105	......	18	...do	9.4	304	1	15	10	30	8.5610	42,956	0.260	
Nov.	13	82	......	180	....do	107	......	17½	Banca...	9.2	304.5		40	8	25	......	......	......	Condemned. Imperfect casting.
Nov.	13	83	44	178	....do	111	4	17¾	...do	9.5	308.5	1		10	30	8.6588	49,905	0.363	
Nov.	13	84	96	177	....do	109	......	17¾	...do	9.5	303.5	1		10	25	8.4562	41,166	0.182	
Nov.	14	85	83	191	....do	108	......	19	...do	9.4	318	1		10	25	8.6888	48,197	0.349	
Nov.	14	86	57	185	....do	109	4	18½	...do	9.5	316.5	1	10	12	30	8.7736	45,218	0.236	
Nov.	14	87	37	176	....do	108	3	17½	...do	9.5	300.5	......	......	10	30	8.5108	47,548	0.378	
Nov	14	88	39	178	....do	110	3	17¾	...do	9.4	308.75	......	......	10	30	8.5732	42,939	0.215	

Manufacture of 2.5-inch bronze guns at the West Point foundery, 1878—Continued.

Castings.			Metal used.								Time.			Test of samples.			Remarks.
Date.	Foundery number.	Register number.	Weight of copper.	Brand of copper.	Bronze. Heads.	Bronze. Chips.	Weight of tin.	Brand of tin.	Per cent. of tin.	Total weight.	Melting copper.	From adding tin to casting.	Between pouring and removing casting.	Specific gravity.	Tenacity.	Extension per inch at rupture.	
			Lbs.		*Lbs.*	*Lbs.*	*Lbs.*			*Lbs.*	*H. M.*	*M.*	*H. M.*		*Lbs.*	*Inches.*	
Nov. 1	23	143	185	Quincy	115	7	20½	Banca	10	327.5	1 15	15	40	8.8130	44,771	0.172	
Nov. 1	24	27	200	....do	99	4	22	..do	9.9	325	2 0	12	1 0	8.7989	49,980	0.243	
Nov. 1	25	......	161	....do	151	5	18	..do	10.8	335	1 20	14	45	8.8118	52,330	0.29	Condemned, after proof, for defects in gun.
Nov. 1	26	198	152	....do	153	4	17	....	10	326	1 45	15	30	8.659	39,393	0.123	The bronze "heads" used should really have been classed chips, giving 11.5 per cent. tin.
Nov. 2	27	176	199	....do	138	5	14	Banca	8	356	1 45	16	35	8.8366	51,350	0.38	
Nov. 2	28	41	168	....do	157	4	16¾	..do	9.5	340.25	....	12	40	8.7580	44,253	0.215	
Nov. 2	29	......	177	....do	154	5	17¾	..do	9.6	368.75	1 40	20	45	8.7972	50,406	0.280	Condemned after proof, for defects in body of gun.
Nov. 4	30	166	190	....do	129	4	20	..do	9.5	352	1 20	15	40	8.6965	42,651	0.137	New chill.
Nov. 4	31	178	215	....do	100	3	21½	..do	9.4	339.5	1 30	15	35	8.8215	51,795	0.32	
Nov. 4	32	182	222	....do	110	2	21¾	..do	9.2	365.25		15	35	8.6780	48,686	0.18	
Nov. 4	33	180	217	....do	93	4	21¾	..do	9.4	335.75	....	16	40	8.8280	53,184	0.30	
Nov. 4	34	122	206	....do	85	3	22	..do	9.8	316	1 20	15	30	8.7830	46,990	0.25	
Nov. 4	35	......	225	....do	70	2	22½	..do	9.3	319.5	1 10	12	35	8.8195	53,960	0.48	Condemned after proof, for defects in body of gun.
Nov. 5	36	94	217	....do	130	3	21½	L. & F.	9.5	371.5	1 40	15	35	8.8226	50,154	0.345	
Nov. 5	37	178	211	....do	127	4	20	..do	9.2	362	1 10	12	35	8.8120	43,980	0.207	
Nov. 5	38	43	261	....do	71	3	26	..do	9.3	361	1 20	12	35	8.7876	50,332	0.344	
Nov. 5	39	169	316	....do	......	2	35½	..do	10	355.5	1 5	15	35	8.8055	46,369	0.41	
Nov. 5	40	48	326	....do	......	3	36½	..do	10	365.25	1 30	12	25	8.8068	54,806	0.429	
Nov. 5	41	119	210	....do	105	......	23½	..do	9.9	338.26	1	12	30	8.72	56,727	0.41	
Nov. 6	42	84	193	....do	105	4	19¾	..do	9.6	321.75	1 10	15	35	8.8124	51,809	0.319	
Nov. 6	43	40	204	....do	105	......	20¼	..do	9.4	329.25	1 10	12	30	8.8886	46,254	0.19	
Nov. 6	44	......	194	....do	105	......	30¾	..do	14.3	338	1 15	10	35	8.5551	34,246	0.079	Condemned. Double charge found to have been accidentally added.
Nov. 6	45	120	188	....do	115	3	18¾	..do	9.5	324.75	1 10	8	28	8.7877	51,084	0.319	
Nov. 6	46	64	197	....do	107	2	19¾	..do	9.4	325.75	55	10	30	8.7717	42,381	0.181	
Nov. 6	47	184	192	....do	111	3	19¼	..do	9.5	325.25	1 5	8	35	8.8188	52,656	0.328	
Nov. 7	48	58	195	....do	114	2	19¼	..do	9.5	330.5	1	6	28	8.7280	39,097	0.135	
Nov. 7	49	131	196	....do	109	4	19¼	..do	9.4	328.5	1 10	8	35	8.7765	52,460	0.339	

Nov.	7	50	......	194	....do.....	116	4	19¼	...do....	9.4	333.25	1	15	8	35	8.6277	42,573	0.246	Condemned after proof, for hole in chase.
Nov.	7	51	79	196	....do.....	114	3	19¼	...do....	9.5	331.5	1	10	8	30	8.7651	48,247	0.293	
Nov.	7	52	39	186	....do.....	117	2	18¾	...do....	9.4	323.5	......		....	35	8.6279	53,900	0.390	
Nov.	7	53	75	180	....do.....	115	3	19	...do....	9.5	326	1	15	10	30	8.7984	49,213	0.390	
Nov.	8	54	77	172	....do.....	100	4	17¼	...do....	9.6	298.75	1	5	8	35	8.7691	46,309	0.293	
Nov.	8	55	47	175	....do.....	102	3	17¾	...do....	9.5	297.5	1	10	10	30	8.7613	44,294	0.258	
Nov.	8	56	46	173	....do.....	119	3	17¾	...do....	9.5	312.25	1	15	15	35	8.5864	45,440	0.338	
Nov.	8	57	......	174	....do.....	106	2	17¾	...do....	9.4	301.25	1	15	12	35	......	......	......	Condemned. Imperfect casting.
Nov.	8	58	62	179	....do.....	113	2	18	...do....	9.5	312	1		16	35	8.7131	40,469	0.179	
Nov.	8	59	......	177	....do.....	114	3	17¾	...do....	9.5	311.75	1	5	10	30	8.3821	35,109	0.154	Condemned.
Nov.	9	60	81	178	....do.....	114	4	17¾	...do....	9.5	313.75		45	14	30	8.4383	41,850	0.151	
Nov.	9	61	13	177	....do.....	110	3	17¾	...do....	9.5	307.75	1	5	10	25	8.5344	38,117	0.204	
Nov.	9	62	35	175	....do.....	108	2	17¾	...do....	9.4	302.5	1		10	35	8.5461	38,307	0.164	
Nov.	9	63	......	175	....do.....	115	4	17¾	...do....	9.5	311.5	1	5	10	30	8.6241	40,771	0.181	Condemned. Imperfect casting.
Nov.	9	64	52	173	....do.....	113	3	17¾	...do....	9.4	306.25	1	5	12	28	8.7802	45,444	0.220	
Nov.	9	65	38	176	....do.....	108	2	17¾	...do....	9.4	303.5	1	15	10	25	8.7406	43,152	0.201	
Nov.	11	66	......	176	....do.....	108	......	17¾	Banca...	9.4	301.5	1	15	10	30	7.6244	33,029	0.216	Condemned after proof. Cavity in bore of gun.
Nov.	11	67	26	167	....do.....	112	......	16¾	...do....	9.4	295.75	1	15	10	35	8.7538	44,601	0.246	
Nov.	11	68	......	175	....do.....	110	......	17¾	...do....	9.4	302.5	1		10	30	8.5284	41,653	0.295	Condemned. Imperfect casting.
Nov.	11	69	89	176	....do.....	107	3	17¾	...do....	9.4	303.5	......		10	35	8.8388	50,762	0.394	
Nov.	11	70	......	192	....do.....	96	......	19¼	...do....	9.3	307.1	1		15	45	8.6004	39,196	0.133	Condemned after proof. Defects in chase.
Nov.	11	71	17	196	....do.....	91	2	19¼	...do....	9.3	308.5	1	10	....	40	8.7714	44,686	0.218	
Nov.	12	72	......	176	....do.....	107	......	17¾	...do....	9.4	300.75	1	15	15	30	......	......	......	Condemned. Imperfect casting; honey-combed on each side along longitudinal joint of chill.
Nov.	12	73	......	189	....do.....	106	......	19	...do....	9.4	314	1	15	15	35	......	......	......	Condemned. Imperfect casting; honey-combed on each side along longitudinal joint of chill.
Nov.	12	74	......	185	....do.....	107	......	18½	...do....	9.4	310.5	1	5	10	30	......	......	......	Condemned. Imperfect casting; honey-combed on each side along longitudinal joint of chill.
Nov.	12	75	100	188	....do.....	104	3	18¾	...do....	9.4	313.75	1	10	15	35	8.7225	45,470	0.307	Small cracks had formed in chill, more especially where two sections united. These were hammered smooth before this casting.
Nov.	12	76	......	190	....do.....	105	......	19	...do....	9.4	314	1	15	15	35	8.7389	43,225	0.212	Condemned. Imperfect casting.
Nov.	12	77	28	180	....do.....	105	......	18	...do....	9.4	308	......		....	35	8.5545	41,158	0.182	
Nov.	12	78	......	177	....do.....	109	3	17¾	...do....	9.4	306.5	......		....	35	8.5601	42,361	0.250	Condemned. Imperfect casting.
Nov.	12	79	......	191	....do.....	110	......	19	L. & F...	9.4	320	1		10	30	8.4839	39,295	0.203	Condemned after proof. Defect in body.
Nov.	13	80	29	191	....do.....	110	3	19	...do....	9.4	323	1	10	15	35	8.7095	50,154	0.363	
Nov.	13	81	56	181	....do.....	105	......	18	...do....	9.4	304	1	15	10	30	8.5610	42,956	0.260	
Nov.	13	82	......	180	....do.....	107	......	17¾	Banca...	9.2	304.5		40	8	25	......	......	......	Condemned. Imperfect casting.
Nov.	13	83	44	178	....do.....	111	4	17¾	...do....	9.5	308.5	1		10	30	8.6588	49,905	0.363	
Nov.	13	84	96	177	....do.....	109	......	17¾	...do....	9.5	303.5	1		10	25	8.4562	41,166	0.182	
Nov.	14	85	83	191	....do.....	108	......	19	...do....	9.4	318	1		10	25	8.6888	48,137	0.349	
Nov.	14	86	57	185	....do.....	109	4	18½	...do....	9.5	316.5	1	10	12	30	8.7736	45,218	0.236	
Nov.	14	87	37	176	....do.....	108	3	17¾	...do....	9.5	300.5	......		10	30	8.5103	47,548	0.376	
Nov	14	88	39	178	....do.....	110	3	17¾	...do....	9.4	308.75	......		10	30	8.5732	42,939	0.215	

Manufacture of 2.5-inch bronze guns at the West Point foundery, 1878—Continued.

Castings.			Metal used.								Time.			Test of samples.			Remarks.
Date.	Foundery number.	Register number.	Weight of copper.	Brand of copper.	Bronze. Heads.	Bronze. Chips.	Weight of tin.	Brand of tin.	Per cent. of tin.	Total weight.	Melting copper.	From adding tin to casting.	Between pouring and removing casting.	Specific gravity.	Tenacity.	Extension per inch at rupture.	
			Lbs.		*Lbs.*	*Lbs.*	*Lbs.*			*Lbs.*	*H. M.*	*M.*	*H. M.*		*Lbs.*	*Inches.*	
Nov. 14	89	55	182	Quincy....	109	3	18	Banca...	9.4	312	1 15	5	35	8.6841	49,119	0.361	
Nov. 14	90	199	179	....do	108	......	17⅘	...do	9.4	304.8	1 20	10	25	8.6941	46,878	0.304	
Nov. 14	91	45	180	....do	109	2	18	...do	9.4	309	1	8	40	8.6128	44,908	0.248	
Nov. 15	92	123	178	....do	112	......	17¾	...do	9.4	307.75	1 5	5	30	8.7879	52,393	0.408	
Nov. 15	93	73	178	....do	112	3	17½	...do	9.4	310.5	1 10	15	25	8.6501	48,214	0.370	
Nov. 15	94	36	178	....do	114	......	17¾	...do	9.4	309.75	1	12	30	8.5149	42,467	0.281	
Nov. 15	95	164	183	....do	114	......	18¼	...do	9.4	315.25	1 5	10	30	8.5627	43,062	0.233	
Nov. 15	96	54	178	....do	112	4	17¾	...do	9.5	311.75	1	10	40	8.4547	48,727	0.372	
Nov. 15	97	51	180	....do	122	3	18	...do	9.5	323	1 5	10	30	8.5384	43,046	0.231	
Nov. 15	98	16	175	....do	116	2	17½	...do	9.5	310.5	1 5	10	25	8.3416	39,900	0.222	
Nov. 16	99	48	175	....do	116	......	17½	...do	9.4	308.5	1 10	10	25	8.6632	50,423	0.375	
Nov. 16	100	49	178	....do	110	3	17¾	...do	9.4	308.75	1	10	30	8.6910	49,119	0.324	
Nov. 16	101	101	170	....do	123	......	17	...do	9.4	310	1 5	10	25	8.5325	42,545	0.256	
Nov. 16	102	61	175	....do	111	2	17½	...do	9.1	315.5	1	5	25	8.6219	44,011	0.260	
Nov. 16	103	24	177	....do	116	......	17¾	...do	9.4	310.75	1 10	10	30	8.7477	45,976	0.232	
Nov. 16	104	76	180	....do	112	3	18	...do	9.5	313	1	10	30	8.4784	43,823	0.232	
Nov. 18	105	18	183	....do	112	......	18¼	...do	9.4	313.25	1 15	10	25	8.6637	40,482	0.145	
Nov. 18	106	33	174	....do	112	3	17¼	...do	9.4	306.25	1	5	25	8.7320	41,569	0.145	
Nov. 18	107	......	186	....do	104	......	18⅕	...do	9.2	308.2	1 5	5	30	8.4509	40,483	0.171	Condemned after proof; defects in gun.
Nov. 18	108	1	186	....do	104	3	18½	...do	9.4	311.5	1 10	10	25	8.6290	40,575	0.169	
Nov. 18	109	42	177	....do	113	3	17¾	...do	9.5	310.75	1 10	10	25	8.6363	44,797	0.240	
Nov. 18	110	......	183	....do	109	......	18¼	...do	9.4	310.25	1 15	15	30	....	....	....	Condemned—imperfect casting.
Nov. 18	111	30	190	....do	110	......	19	...do	9.4	319	1 15	12	30	8.5883	46,320	0.290	
Nov. 19	112	53	186	....do	112	3	18½	...do	9.4	319.5	1 15	10	25	8.7548	52,525	0.365	
Nov. 19	113	20	184	....do	112	......	18¼	...do	9.4	314.25	1 0	10	30	8.7482	44,797	0.281	
Nov. 19	114	21	183	....do	111	2	18¼	...do	9.4	314.25	1 10	12	28	8.5397	47,272	0.345	
Nov. 19	115	92	186	....do	109	......	18½	...do	9.4	313.5	1 0	10	30	8.6863	44,452	0.227	
Nov. 19	116	161	187	....do	108	3	18½	...do	9.4	316.5	1 5	15	25	8.4784	48,225	0.232	
Nov. 19	117	......	178	....do	113	2	17¾	...do	9.4	310.75	1 10	15	25	8.3630	37,424	0.116	Condemned.
Nov. 19	118	19	180	....do	99	......	18	...do	9.4	297	1 15	10	30	8.8044	51,596	0.265	
Nov. 20	119	114	182	....do	110	2	18⅕	...do	9.4	312.2	1 20	15	35	8.6096	40,676	0.223	
Nov. 20	120	106	182	....do	110	......	18	...do	9.4	310	1 10	15	30	8.7742	49,092	0.288	
Nov. 20	121	74	173	....do	116	......	17¼	...do	9.4	306.25	1 0	15	25	8.7483	56,333	0.485	
Nov. 20	122	90	174	....do	116	......	17¼	...do	9.4	307.25	1 5	15	25	8.5505	43,441	0.191	

Nov.	20	123	97	179	....do	112	3	18	...do	9.5	312	1	10	10	30	8.7312	44,204	0.222
Nov.	20	124	22	177	....do	115	......	17¾	...do	9.4	309.75	1	20	15	30	8.6883	50,962	0.850
Nov.	20	125	5	185	....do	102	4	18⅛	...do	9.4	309.5	1	20	15	30	8.7950	52,250	0.331
Nov.	21	126	12	176	....do	112	3	17½	...do	9.4	308.5	1	20	10	30	8.7588	49,242	0.328
Nov.	21	127	28	171	....do	118	......	17	...do	9.4	306	1	25	15	25	8.7606	53,569	0.393
Nov.	21	128	60	177	....do	114	......	17⅛	...do	9.3	309.5	1	20	10	25	8.8227	52,656	0.376
Nov.	21	129	88	174	....do	112	1	17⅛	...do	9.2	314.5	1	15	15	30	8.7795	50,424	0.325
Nov.	21	130	25	173	....do	128	3	17¼	...do	9.5	321.25	1	20	10	28	8.8035	53,245	0.425
Nov.	21	131	59	178	....do	119	......	17¾	...do	9.4	314.75	1	25	12	30	8.6211	47,941	0.430
Nov.	21	132	......	178	....do	119	2	17⅛	...do	9.4	316.5	1	20	20	....	8.6112	44,797	0.282	Condemned after proof—defective.
Nov.	22	133	98	144	....do	136	2	14¾	...do	9.5	296.25	1	30	15	25	8.7221	42,545	0.172
Nov.	22	134	86	179	....do	118	......	18	...do	9.5	315	1	15	15	25	8.4358	41,363	0.166
Nov.	22	135	130	194	....do	100	2	19¼	...do	9.4	315.25	1	20	10	25	8.7732	50,549	0.314
Nov.	22	136	11	189	....do	116	3	18⅝	L. & F.	9.4	326.8	....		10	30	8.6413	44,515	0.229
Nov.	23	137	162	180	....do	116	......	18	...do	9.4	314	....		10	30	8.7857	50,424	0.319
Nov.	23	138	126	180	....do	116	......	18	...do	9.4	314	1	10	10	25	8.7079	41,174	0.133
Nov.	23	139	7	180	....do	116	......	18	...do	9.4	314	1	15	15	25	8.5965	40,474	0.158
Nov.	23	140	6	180	....do	116	5	18	...do	9.5	319	1	10	12	25	8.7272	48,454	0.326
Nov.	23	141	9	174	....do	116	3	17¼	...do	9.4	310.25	1	0	15	30	8.6759	44,437	0.267
Nov.	23	142	169	177	....do	113	......	17¾	...do	9.4	307.75	1	0	15	30	8.7276	42,884	0.180
Nov.	23	143	82	181	....do	114	......	18	...do	9.4	313	1	0	10	25	8.7206	47,941	0.292
Nov.	25	144	170	186	C.F.M.Co.	114	2	18	...do	9.2	320	1	0	10	25	8.7254	44,737	0.233
Nov.	25	145	185	178	....do	114	......	17¾	...do	9.4	309.75	1	10	15	30	8.6985	40,778	0.154
Nov.	25	146	142	160	....do	126	4	16	...do	9.5	306	1	5	10	25	8.7250	43,153	0.200
Nov.	25	147	71	156	....oo	130	2	15½	...do	9.5	303.5	1	0	15	25	8.7782	53,051	0.386
Nov.	26	148	65	176	....do	118	......	17½	...do	9.4	311.5	1	5	10	25	8.8144	40,415	0.213
Nov.	26	149	85	175	....do	117	3	17½	...do	9.5	312.5	1	10	15	25	8.7199	44,797	0.219
Nov.	26	150	3	171	....do	120	......	17	...do	9.4	308	1	10	15	25	8.7870	52,514	0.364
Nov.	26	151	72	172	....do	120	2	17¼	...do	9.5	311.25	1	5	10	20	8.6076	40,969	0.180
Nov.	26	152	10	171	....do	120	......	17	...do	9.4	308	1	0	10	25	8.8096	50,549	0.338
Nov.	26	153	124	171	....do	120	2	17	...do	9.4	310	1	5	15	25	8.4557	39,393	0.194
Nov.	26	154	110	168	....do	125	......	16¾	...do	9.4	309.75	1	10	10	20	8.7371	40,082	0.158
Nov.	27	155	31	170	....do	124	......	17	...do	9.5	311	1	15	15	30	8.8166	43,549	0.173
Nov.	27	156	70	170	....do	124	......	17	...do	9.5	311	1	20	15	25	8.7729	49,092	0.210
Nov.	27	157	167	172	....do	120	3	17½	...do	9.5	312.2	1	0	15	30	8.7365	44,625	0.219
Nov.	27	158	87	170	....do	122	......	17	...do	9.4	309	1	10	12	25	8.7305	42,832	0.164
Nov.	27	159	147	160	....do	130	2	16	...do	9.5	308	1	10	10	25	8.7887	45,302	0.216
Nov.	27	160	134	160	....do	130	3	16	...do	9.5	309	1	15	12	25	8.4808	43,046	0.250
Nov.	27	161	161	170	....do	130	......	17	...do	9.5	317	1	10	15	25	8.4227	40,181	0.192
Nov.	29	162	179	171	....do	130	2	17	...do	9.5	320	1	10	15	25	8.5424	41,158	0.180
Nov.	29	163	66	170	....do	121	......	17	...do	9.4	308	1	15	10	25	8.6397	42,939	0.198
Nov.	29	164	93	170	....do	122	2	17	...do	9.5	311	1	10	15	20	8.7397	43,618	0.264
Nov.	29	165	78	170	....do	121	3	17	...do	9.5	311	1	10	12	25	8.7630	44,011	0.236
Nov.	29	166	67	170	....do	126	......	17	...do	9.5	313	1	5	15	20	8.5859	42,046	0.208
Nov.	29	167	127	170	....do	120	......	17	...do	9.4	307	1	0	10	25	8.5977	41,570	0.172
Nov.	30	168	4	169	....do	126	3	17	...do	9.5	315	1	10	15	30	8.6354	41,370	0.146
Nov.	30	169	8	165	....do	129	2	16½	...do	9.5	312.5	1	5	15	25	8.7004	43,333	0.200
Nov.	30	170	68	154	....do	143	......	15½	...do	9.5	312.5	1	10	12	30	8.7267	42,758	0.200
Nov.	30	171	137	171	....do	130	4	17	...do	9.5	322	1	0	15	20	8.7923	44,515	0.229
Nov.	30	172	80	159	....do	131	......	16	...do	9.5	306	1	10	12	25	8.6240	41,570	0.180
Nov.	30	173	112	155	....do	139	3	15½	...do	9.5	312.5	1	15	15	25	8.6228	41,466	0.180
Nov.	30	174	171	168	....do	132	......	16¾	...do	9.5	316.75	1	0	10	30	8.6049	43,902	0.296

Manufacture of 2.5-inch bronze guns at the West Point foundery, 1878—Continued.

Castings.			Metal used.								Time.			Test of samples.			Remarks.
Date.	Foundery number.	Register number.	Weight of copper.	Brand of copper.	Bronze. Heads.	Bronze. Chips.	Weight of tin.	Brand of tin.	Per cent. of tin.	Total weight.	Melting copper.	From adding tin to casting.	Between pouring and removing casting.	Specific gravity.	Tenacity.	Extension per inch at rupture.	
			Lbs.		*Lbs.*	*Lbs.*	*Lbs.*			*Lbs.*	*H. M.*	*M.*	*H. M.*		*Lbs.*	*Inches.*	
Dec. 2	175	108	157	Quincy....	126	......	15½	Banca..	9.4	298.5	1 5	15	25	8.6801	48,333	0.172	
Dec. 2	176	125	170	....do.....	127	3	17	..do....	9.5	317	1 5	15	25	8.5498	42,832	0.178	
Dec. 2	177	......	173	....do.....	124	......	....	Unkn'n.	....	....	1 20	15	20	....	....	....	Condemned.
Dec. 2	178	......	160	....do.....	140	......	16	...do....	9.5	316	....	15	25	....	....	....	Condemned.
Dec. 3	179	113	167	....do.....	124	......	16¾	L. & F..	9.5	307.75	1 15	15	25	8.6605	38,510	0.126	
Dec. 3	180	163	162	....do.....	129	4	16¼	...do....	9.5	311.25	1 20	12	25	8.5854	36,938	0.148	
Dec. 3	181	69	163	....do.....	130	......	16¼	...do....	9.5	318.25	....	10	25	8.5762	40,796	0.188	
Dec. 3	182	......	166	....do.....	126	3	16¾	...do....	9.5	311.5	1 10	10	30	8.3618	37,424	0.138	Condemned.
Dec. 3	183	99	190	....do.....	102	......	19	...do....	9.4	311	1 5	10	30	8.6128	39,491	0.132	
Dec. 3	184	146	170	....do.....	108	......	17	...do....	9.4	295	1 5	12	25	8.6970	44,515	0.264	
Dec. 3	185	190	168	....do.....	120	......	14	...do....	8.6	302	1 10	15	30	8.7687	54,300	0.371	
Dec. 4	186	159	162	....do.....	130	3	14	...do....	8.9	309	1 10	15	25	8.6824	40,081	0.183	
Dec. 4	187	141	162	....do.....	130	2	14	...do....	8.9	308	1 20	15	25	8.6692	42,151	0.211	
Dec. 4	188	168	160	....do.....	130	3	14¼	...do....	8.9	307.5	1 15	15	25	8.7647	42,430	0.222	
Dec. 4	189	138	164	....do.....	129	2	14	...do....	8.0	300	1 0	15	25	8.7387	48,940	0.338	
Dec. 4	190	136	162	....do.....	129	......	14½	...do....	9.0	305.5	1 15	15	25	8.4416	39,393	0.146	
Dec. 5	191	129	162	....do.....	129	3	14	...do....	8.8	308	1 0	10	25	8.5772	39,987	0.151	
Dec. 5	192	148	164	....do....	125	......	14¼	...do....	8.9	302.5	1 5	15	25	8.7563	46,660	0.250	
Dec. 5	193	196	162	....do.....	130	3	14¼	...do....	8.9	309.25	1 0	12	25	8.5663	40,960	0.211	
Dec. 5	194	172	160	....do.....	130	......	14	...do....	8.9	304	1 0	15	25	8.4807	39,492	0.169	
Dec. 5	195	158	160	....do.....	130	2	14	...do....	8.9	306	1 5	10	25	8.6055	40,575	0.222	
Dec. 5	196	145	178	....do.....	116	......	14¾	...do....	8.5	308.75	1 5	15	30	8.4646	39,492	0.189	
Dec. 5	197	156	160	....do.....	131	3	14	...do....	8.9	308	1 20	15	25	8.5206	40,778	0.158	
Dec. 6	198	187	160	....do.....	130	......	14	...do....	8.9	304	1 0	15	30	8.5686	42,151	0.250	
Dec. 6	199	109	160	....do.....	130	3	14	...do....	8.9	307	1 20	15	25	8.6605	42,545	0.246	
Dec. 6	200	103	160	....do.....	130	......	14	...do....	8.9	304	1 10	15	35	8.4069	39,198	0.141	
Dec. 6	201	104	168	....do.....	122	......	14	...do....	8.6	304	1 0	15	35	8.6499	42,384	0.250	
Dec. 7	202	140	164	....do.....	128	3	14¼	...do....	8.5	309.2	1 15	15	30	8.4934	39,393	0.187	
Dec. 7	203	111	164	....do.....	129	......	14¼	...do....	8.8	307.2	1 5	10	30	8.7978	50,030	0.370	
Dec. 7	204	191	167	....do.....	128	......	14½	..do....	8.7	309.25	1 10	10	30	8.7287	46,060	0.370	
Dec. 7	205	151	160	....do.....	130	......	14	..do....	8.9	304	1 15	15	25	8.7097	45,976	0.248	
Dec. 7	206	165	164	....do.....	130	3	14½	...do....	8.9	311.2	1 5	15	25	8.7350	47,272	0.305	
Dec. 7	207	107	160	....do.....	130	......	14	...do....	8.9	304	1 10	10	25	8.5671	41,280	0.216	
Dec. 7	208	128	166	....do.....	128	......	14½	...do....	8.8	308.25	1 15	20	30	8.3233	39,290	0.245	

Dec.	9	209	131	160	....do	130	3	14	...do	8.9	307	1	20	16	35	8.7097	41,277	0.201	
Dec.	9	210	174	160	....do	130	......	14	...do	8.9	304	1	20	15	25	8.7960	48,144	0.347	
Dec.	9	211	118	160	....do	130	......	14	...do	8.9	304	1	10	10	40	8.6684	40,281	0.188	
Dec.	9	212	105	160	....do	130	2	14	...do	8.9	306	1	5	15	30	8.7798	50,154	0.347	
Dec.	9	213	196	165	....do	130	......	14½	...do	8.9	300.5	1	10	10	40	8.6282	45,020	0.324	
Dec.	9	214	115	160	....do	130	3	14	...do	8.9	307	1	15	15	35	8.6889	48,696	0.389	
Dec.	9	215	144	160	....do	130	......	14	...do	9.0	304	1	5	20	20	8.8307	51,071	0.361	
Dec.	10	216	154	164	....do	130	......	14½	...do	9.0	308.5	1	20	15	25	8.6078	42,439	0.250	
Dec.	10	217	150	161	....do	130	3	14	...do	9.0	308	1	10	15	25	8.6874	48,180	0.387	
Dec.	10	218	194	160	....do	130	......	14	...do	8.9	304	1	10	20	25	8.6416	44,908	0.267	
Dec.	10	219	155	160	....do	130	3	14	...do	8.9	307	1	10	12	25	8.7089	42,545	0.239	
Dec.	11	220	197	160	....do	130	3	14	...do	8.9	306	1	10	15	30	8.7318	46,091	0.272	
Dec.	11	221	102	160	....do	130	3	14	...do	8.9	307	1	20	20	35	8.6743	42,545	0.225	
Dec.	11	222	189	160	....do	130	......	14	...do	8.9	304	1	20	15	30	8.7300	45,415	0.250	
Dec.	11	223	116	160	....do	130	3	14	...do	8.9	304	1	10	15	35	8.7765	48,060	0.333	
Dec.	11	224	192	160	....do	130	3	14	...do	8.9	307	1	5	15	35	8.8458	50,296	0.356	
Dec.	11	225	160	160	....do	130	......	14	...do	8.9	304	1	15	20	25	8.5799	42,256	0.255	
Dec.	11	226	......	160	....do	130	3	14	...do	8.9	307	1	5	15	25	8.7840	50,556	0.382	Condemned—imperfect casting.
Dec.	12	227	177	160	....do	130	......	14	...do	8.9	304	1	10	12	28	8.6639	39,898	0.155	
Dec.	12	228	175	160	....do	130	3	14	...do	8.9	307	1	15	10	30	8.6982	48,696	0.384	
Dec.	12	229	188	160	....do	130	......	14	...do	8.9	304	1	5	10	35	8.6212	41,653	0.269	
Dec.	12	230	117	160	....do	130	2	14	...do	8.9	306	1	20	20	35	8.6744	48,300	0.345	
Dec.	12	231	139	153	....do	135	......	14	...do	9.0	301	1	10	15	30	8.5056	46,369	0.338	
Dec.	12	232	153	160	....do	130	3	14	...do	8.9	307	1	25	15	35	8.7250	50,675	0.379	
Dec.	12	233	182	160	....do	130	......	14	...do	8.9	304	1	10	15	25	8.7089	50,424	0.408	
Dec.	13	234	183	160	....do	130	3	14	...do	8.9	307	1	20	15	30	8.7262	42,046	0.228	
Dec.	13	235	157	160	....do	130	......	14	...do	8.9	304	1	10	15	30	8.5909	44,452	0.342	
Dec.	13	236	135	160	....do	130	3	14	...do	8.9	307	1	15	10	25	8.7288	42,757	0.208	
Dec.	13	237	193	160	....do	130	......	14	...do	8.9	304	1	5	10	20	8.8382	50,424	0.390	
Dec.	13	238	133	160	....do	130	......	14	...do	8.9	304	1	10	15	30	8.6966	41,363	0.208	
Dec.	13	239	186	160	....do	130	......	14	...do	8.9	304	1	15	....	25	8.8387	55,289	0.461	

Weight of finished gun 113 pounds.
The percentage of tin was calculated on the supposition that the "heads" contained 10 per cent., which will be seen to have been frequently too great an amount.

A feature incidental to the casting, but which is not shown in the records on account of the meagerness and uncertainty of the information obtained, was the extreme variations of temperature and fluidity in the different crucibles of melted copper designed for a charge. During personal observation of many castings, on no occasion could even an unskilled witness fail to notice the differences between the contents of the two ladles. Sometimes the metal in one crucible would be exceedingly liquid, while the other was almost pasty; sometimes both crucibles were very hot, though to an unequal extent; at other times both quite dull. The defects or differences resulting from this irregularity, whatever may have been their extent, might have been corrected had the charges been melted in a furnace.

Attached to this report are extracts from a publication by Lieut. Michael Levitzky, of the Russian navy, upon the fabrication of bronze guns, which have been taken from the *Revue d'Artillerie*, October, 1876

* * * The most complete experiments and the greatest success in the improvements applied to the fabrication of guns are due to Col. Alexander Lavrov, of the artillery. His works commenced by a very complete study upon bronze guns cast in accordance with a series of tests made in 1868 at Liége, in the presence of experienced artillerists. These experiments refer to the temperature of the metal when poured, the rapidity of cooling, the effect of annealing, and the proportion of the ingredients. The following are some of the principal results obtained by Colonel Lavrov:

Number of bars.	The metal fused.	The metal cooled.	Annealing.	Specific gravity. Turnings.	Specific gravity. Bars.	Resistance to rupture.	Elastic limits.
						Pounds.	Pounds.
4–5	Rapidly	Rapidly	Without	8.841	8.740	70,106	47,729
21–19	Slowly	do	do	8.855	8.563	54,367	43,332
6–7	Rapidly	do	With	8.863	8.726	62,758	46,629
16–47	Slowly	do	Without	8.805	8.649	50,293	43,723
15–13	do	Slowly	do	8.837	8.583	49,777	41,503

These results prove among other things that it is best to cool the metal rapidly while it is in the liquid state, and to hasten the cooling even after solidification.

This suggested to Colonel Lavrov the idea of discarding in future the method of casting in sand molds and of using iron molds instead. Such molds, which produce a sudden chilling of the metal, impart to it considerable strength, and moreover have the advantage of possessing an invariable shape. The metal consequently solidifies into a volume the size of which has been accurately calculated in advance. Another modification was designed with the intention of assuring uniformity in the shrinkage, so as to supply from the liquid metal that diminution of volume which occurs while passing from the liquid to the solid state.

To this end Colonel Lavrov so designed the interior profile of the mold that each of the transverse sections should be at least equal to the lowest section, so that, solidification commencing at the bottom, the liquid metal might feed the lower parts as fast as and to the extent that the solidification occurred.

The old mode of casting with the breech down was then discarded, and from that time the chase formed the lower part of the mold. Moreover, there is another advantage derived from this mode of casting. During the first moments of cooling the gun may be considered a vessel with thin walls filled with a very heavy liquid. This will contract as it cools, and, if the breech be down, will be suspended by means of the trunnions, which consequently have to sustain the entire weight of the gun. This may also be the cause, due to the unequal shrinking of the different parts, of producing numerous small cracks in such weak spots as the rear of the trunnions, which are filled with white metal, the fusibility of which keeps it liquid longer than the rest of the mass.

In order to assure the mixture of the upper parts of the casting a sinking-head is placed above the breech. Its cooling is retarded by a sand-head placed on top of the

mold proper. This part of the mold, inclosed in sand, forms a reservoir of fluid metal, which supplies the space produced by the contraction as fast as it occurs.

The trunnions when cast have the shape of trapezoidal prisms. With this form they have the advantage of being able to descend freely with the rest of the casting during the contraction of the mass. This, however, refers to small castings. For large calibers it is far preferable to cast the trunnions separately attached to a ring, which is subsequently heated, slipped over the gun, and shrunk into place. * * *

We can now pass to an examination of some of the details in the fabrication of cannon; such as has been proposed by Colonel Lavrov, and such as he has actually tried at the arsenal at St. Petersburg.

The mold in which the guns are cast is composed of three or four cast-iron flasks, each of which is formed in two parts, connected together by bolts, and provided with trunnions or handles to facilitate the manipulation of the mold and its disposition in the pit.

The assembling of the mold is commenced by laying a cast-iron bed-plate, covered by a mixture of two parts of broken fire-brick and one part of black refractory sand. * * * Upon this bed-plate is placed the muzzle section of the mold (A, Figs. 1, 2, and 14, Plate VII), forming on the exterior the frustum of a right pyramid, and on the interior a truncated cavity, divided into two parts and united together by six bolts. As this part, after the solidification of the casting, is only lifted when laid horizontally, it is not furnished with trunnions like the other sections of the mold. The following section (B) contains the trunnions of the gun. It is also divided into two parts, connected together by four bolts, and furnished with handles. The position of the trunnions is marked by two deep prismatic recesses, which are symmetrically divided by the plane of union of the two parts of the flask.

These recesses commence at a height of 3 or 4 inches above the trunnions and reach almost to the bottom of the flask A. Toward each end the recesses gradually diminish in depth, and their surfaces as gradually coincide with that of the interior of the mold. The breech section C differs only from section B in the absence of the recesses for the trunnions and by an enlargement made in the upper part of the mold.

Sometimes, as in guns larger than 9-pounders, the flask C is replaced by two flasks, the lower of which is made with thick, the upper with thin walls. Finally, the mold of the sinking-head D is so made as to secure a gradual cooling of the metal. This accounts for its being made in the old-fashioned way of sand. The entire interior of the mold is then painted with coke-wash, and afterwards with a heavy coat of the same, until the surface assumes a bright metallic appearance.

Figs. 3, 4, and 5 represent the plan of the muzzle part of the flask, the section of the part for the trunnions and the section of the part for the sinking-head.

Trunnions for mortars are cast separately in special flasks, Figs. 6 and 7. * * *

The different sections of the flask are assembled in the pit of the foundery on the cast-iron bed-plate, which rests on the cylinder of an hydraulic press.

In order to support the mold, the upper sections of the flask are held by two chains fastened into the walls of the pit, and the bottom of the section for the chase is secured by means of an especial frame (Fig. 14, E, and Fig. 8), the upper plate of which is cut to the contour of the flask and the lower pierced through the center with a round orifice. The use to which this is put will be further explained.

Above that portion of the mold which contains the sinking-head is placed the cap F (Fig. 9), which is united to the bed-plate by four rods (G, Fig. 14), always kept in a state of tension by means of the springs H pressing against the heads of bolts U at the ends of the rods and against the under surface of the bed-plate R.

Within the cap is inserted an earthen tube, *r* (Fig. 10), and above it a cast-iron tube of the same dimensions, but connected with a rectangular trough L (Fig. 11), which in its turn is surmounted by the compressor-block M (Fig. 12).

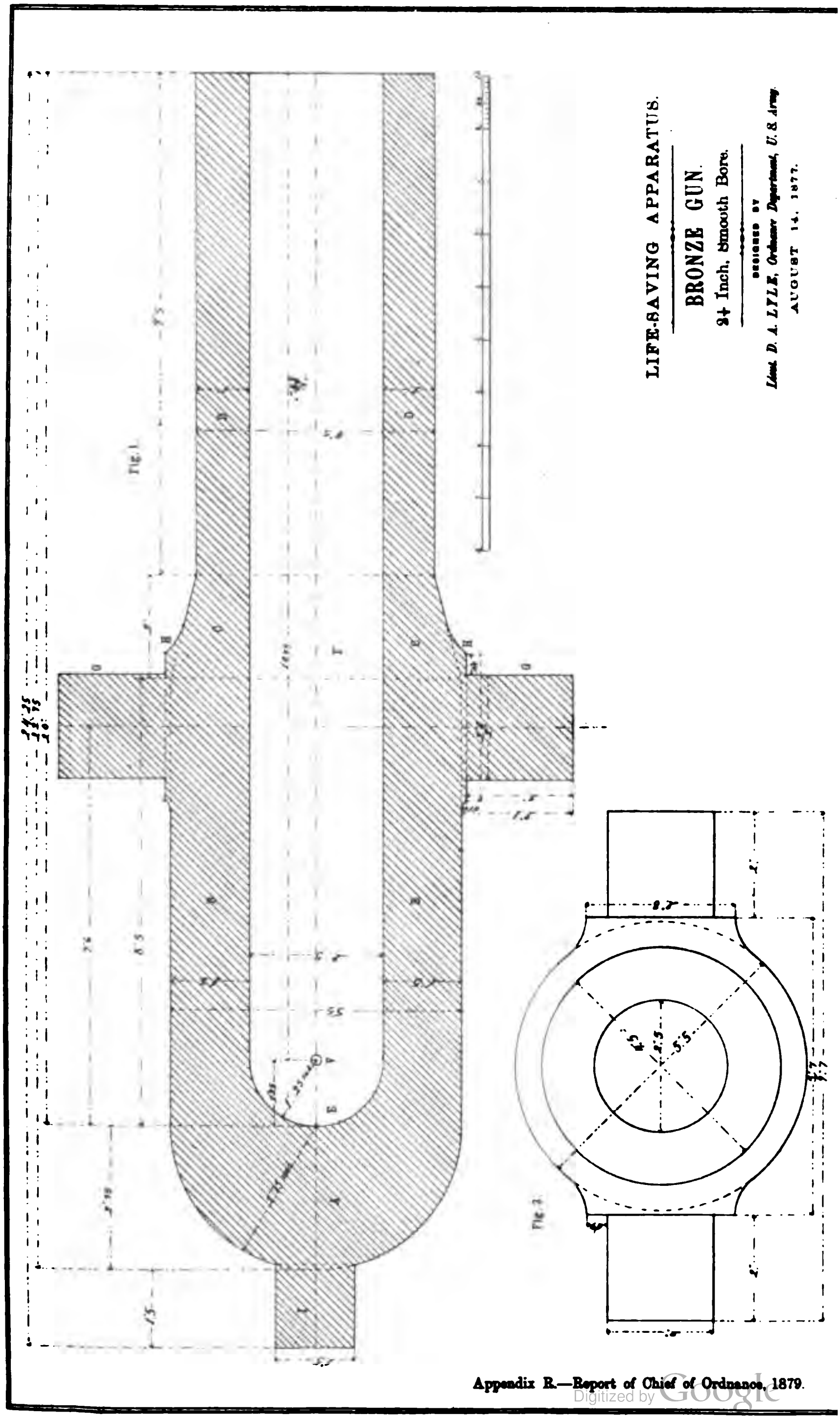
A conical projection, *m*, is attached to the under surface of the block, which is pierced at its four corners with holes, through which pass the uprights N (Fig. 14), which reach to the bottom of the pit, where they hold suspended a thick cast-iron plate, O, upon which is applied the piston of an hydraulic jack.

At the moment of casting, the entire arrangement, M, N, O, is suspended from a crane, and the extremity of the conical projection is from 2 to 2.5 inches above the upper orifice of the tube *l*. But hardly is the mold filled with metal when the chain of the crane is lowered and the hydraulic pressure applied.

The piston Q presses firmly against the plate O, which, by means of the uprights N, pulls down the compressor-block M. The conical projection *m* closes the upper orifice of the tube *l*, and the tube *r* is forced into the liquid metal some 20 inches (50 c. m.)

In order that the metal may not escape from below, the lower opening of the section of the flask for the chase is closed by means of a disk (Fig. 13) about 3.5 inches thick, 0.5 inch of this thickness fitting into the flask and the remainder into a recess cut in the center of the inner plate of the frame E (Fig. 8). The whole is carefully daubed with sand in such manner as to prevent all possible escape of metal.

* * * * * * * *


LIFE-SAVING APPARATUS.
BRONZE GUN.
2½ Inch, Smooth Bore.
DESIGNED BY
Lieut. D. A. LYLE, Ordnance Department, U.S. Army.
AUGUST 14, 1877.
Fig. 1.
Fig. 2.

Chill No. 1.

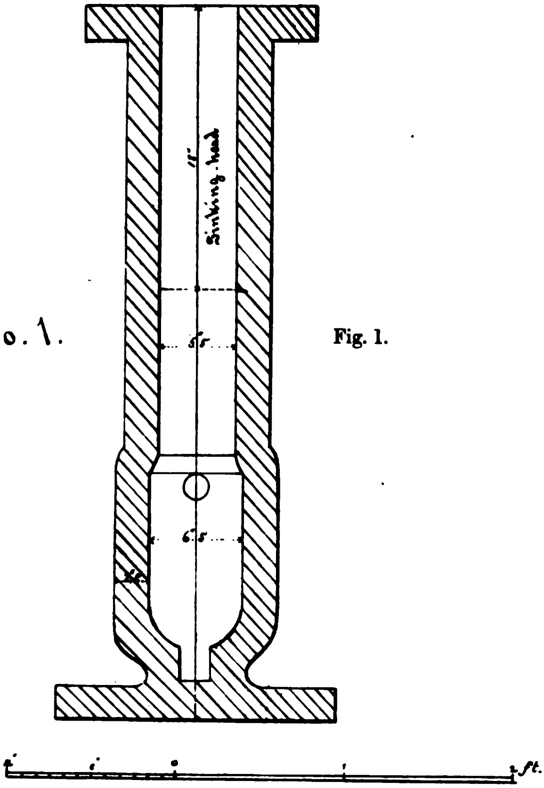
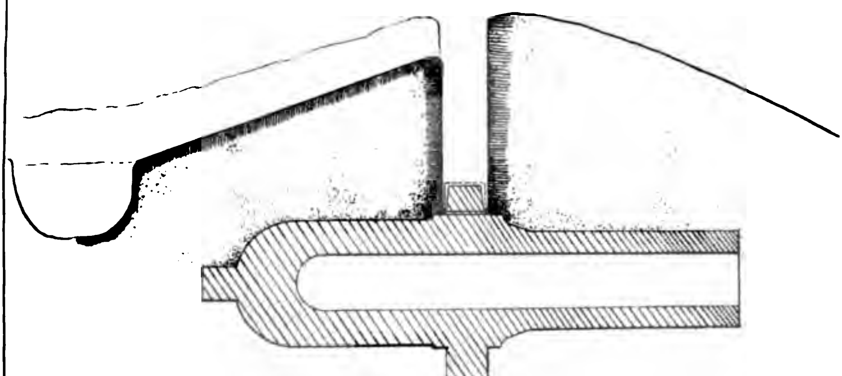


Fig. 1.

Fig. 2.

Burning on new trunnion.



Chill No. 1.

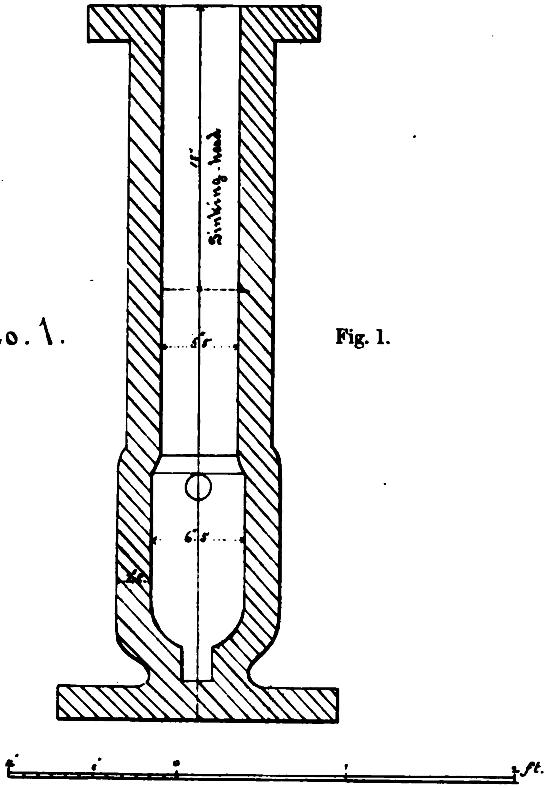
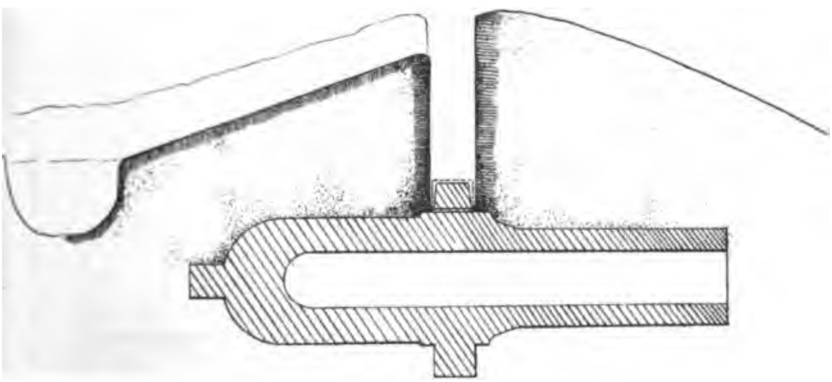
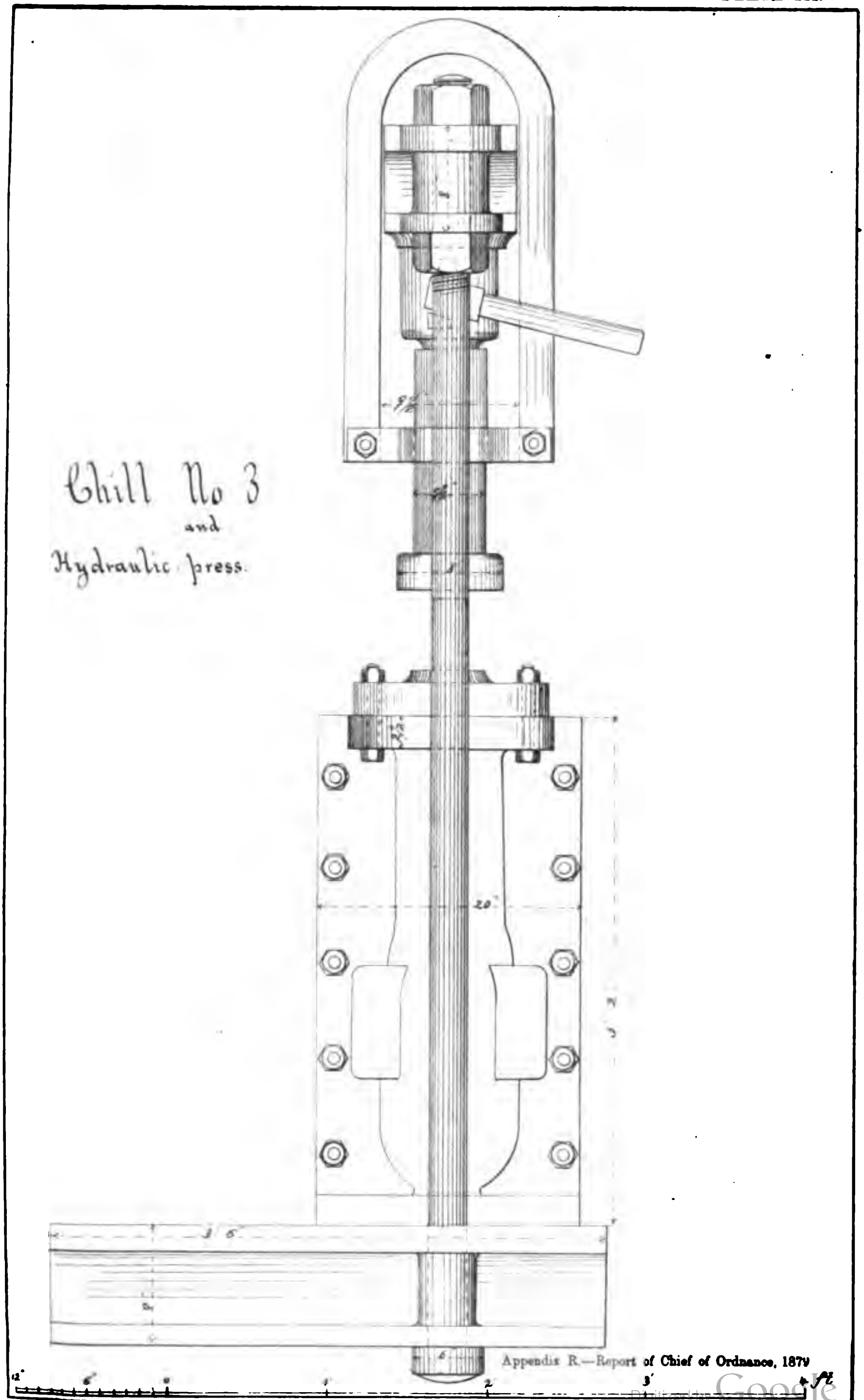


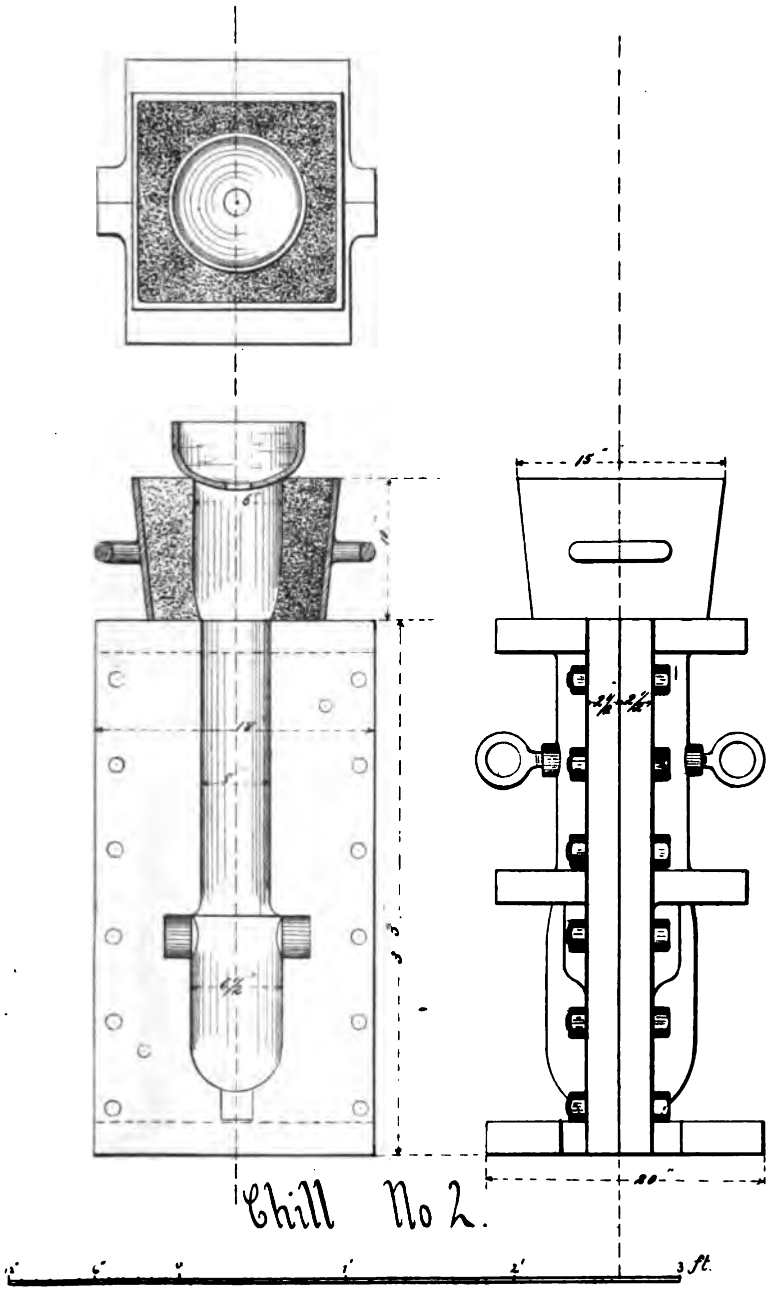
Fig. 1.

Fig. 2.

Burning on new trunnion.




Chill No 3
and
Hydraulic press.
20"
3' 6"
12"
6"
0
1
2
3'
4 ft



Chill No 2.

Fig. 1.

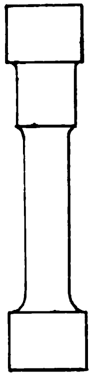


Fig. 2.

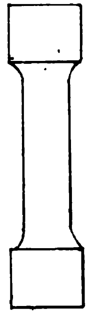


Fig. 3.

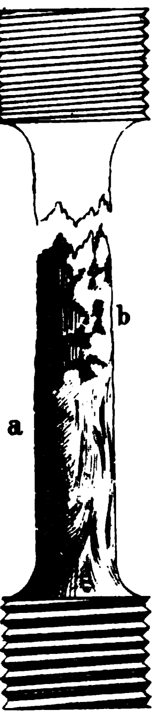


Fig. 4.

Sinking-head of gun No. 239.

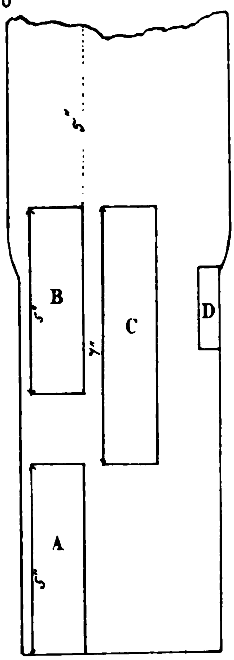


Fig. 5.

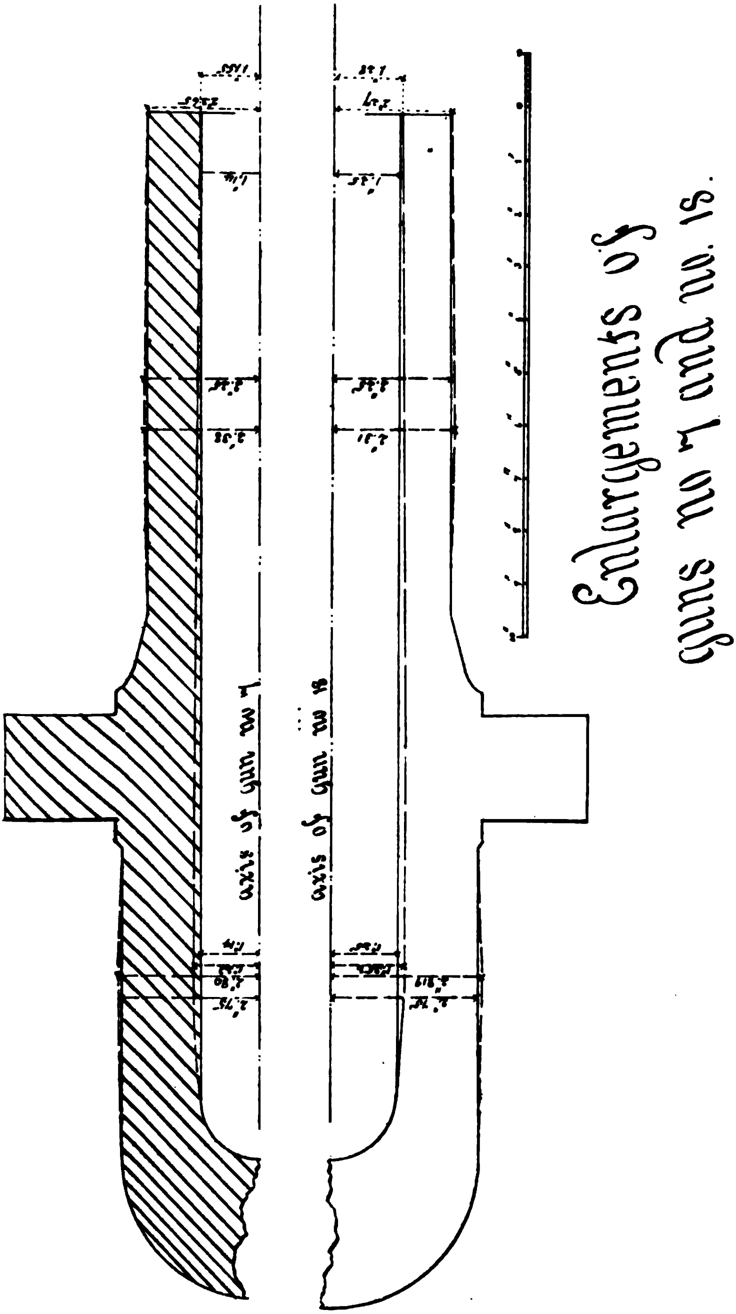
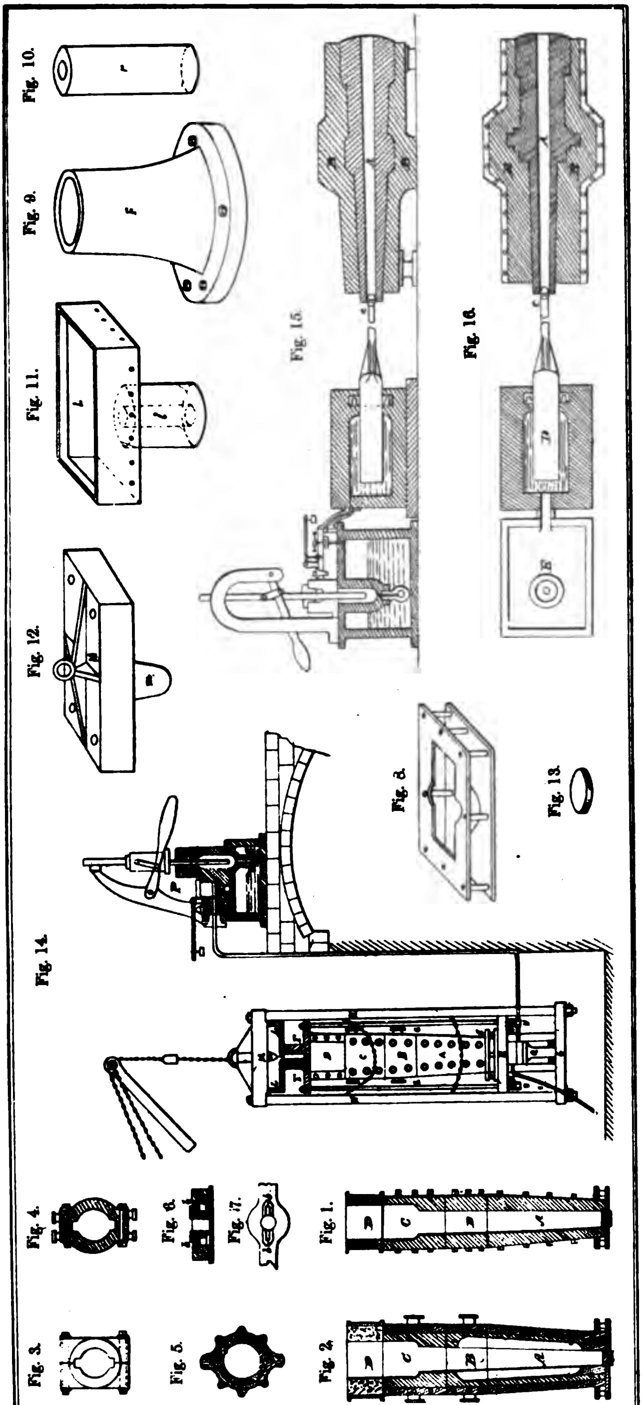

axis of gun no 7
axis of gun no 18
Enlargements of guns no 7 and no. 18.

PLATE VII.



Appendix R.—Report of Chief of Ordnance, 1879

APPENDIX 8.

DESCRIPTION OF THE LYLE-EMERY GRAPPLE SHOT.

Lieut. D. A. LYLE, Ordnance Department.

Four plates.

This projectile was devised by Lieut. D. A. Lyle, Ordnance Department, U. S. A., and Mr. C. E. Emery, draughtsman at the National Armory. It is intended for use in connection with the 2½-inch Lyle gun for life-saving purposes.

DESCRIPTION.

Shot No. 1, *Plate I*, *marked A* 1.

This is an elongated, solid, cast-iron, smooth-bore projectile, with a wrought-iron base and shank. In form the shot is cylindro-ogival. The radius of the ogival head is equal to the diameter of the projectile. An axial cavity, 1.25 inches (3.175 centimeters) deep is bored in the rear end of the shot, upon whose interior cylindrical surface is cut a female screw-thread to engage the screw on the wrought-iron base. The base has a cylindrical axial cavity drilled through it, with a rounded groove on one side to accommodate the stop and stop-spring. The front end of this cavity is enlarged by counter-boring, to allow the necessary longitudinal play of the shank-head in opening and closing the flukes. The screw on this end fits that in the body of the shot. At the rear end of the base are cut five sectoral slots, equidistant circumferentially. These slots receive the heads of the flukes, which are fastened to the base at these points by rivets. Circular grooves are milled out between the slots to allow the insertion of the rivets. The shank is of forged wrought iron. The front end of this bolt has a screw-thread, upon which, after insertion in the axial cavity of the base, a nut is placed. This end of the bolt is riveted after screwing on the nut. A rectangular groove on one side of the shank receives the stop and spring. Five lugs, placed equidistantly around the shank near the forward end, serve as points of attachment for the links that extend the flukes. The rear end of the shank contains an eye-hole for attaching the line in firing. Each link is composed of two flat pieces of Troy steel, with holes at each end to receive the rivets that connect them with the shank and fluke. The flukes, five in number, are also made of Troy steel. Each fluke has a rounded notch near its upper or forward end to accommodate the corresponding lug on the shank when closed. All edges or angles are carefully rounded. The details of form and construction had to be such as would permit the use of the projectile in the 2½-inch gun already in the service, and prevent the entanglement of the line as much as possible in firing.

DIMENSIONS AND WEIGHT.

	Inches.		Centimeters.
Total length of body and base	13.50	=	34.289
Length of ogival head	2.17	=	5.5118
Radius of head	2.50	=	6.350
Length of cylindrical part	9.83	=	24.967
Diameter of cylindrical part	2.50	=	6.350
Axial cavity—Length	1.25	=	3.175
Diameter	1.50	=	3.810
Base—Total length	2.75	=	6.985
Body—Length	1.50	=	3.810
Diameter	2.50	=	6.350
Screw-thread—Length	1.25	=	3.175
Diameter	1.675	=	4.253
Axial cavity—Length	1.00	=	2.54
Diameter	0.625	=	1.587
Width of slot for stop	0.24	=	0.609
Counter-bore—Length	1.75	=	4.445
Diameter	1.125	=	2.857
Stop—Total length	2.10	=	5.334
Width	0.24	=	0.609
Greatest thickness	0.20	=	0.508
Least thickness	0.14	=	0.355
Height of shoulder	0.06	=	0.152
Distance of shoulder from rear end	1.25	=	3.175
Shank—Total length	13.25	=	33.654
Length of screw-thread	0.65	=	1.651
Diameter of screw-thread	0.625	=	1.587
Nut—Diameter	1.125	=	2.857
Thickness	0.625	=	1.587
Length from plane of base	10.50	=	26.670
Distance from base to center of eye-hole	10.00	=	25.400
Diameter of eye-hole	0.40	=	1.016
Width at eye	1.00	=	2.540
Thickness at eye	0.40	=	1.016
Diameter of neck	0.625	=	1.587
Stop slot—Length	2.10	=	5.334
Width	0.24	=	0.609
Depth	0.10	=	0.254
Lugs—Number of	Five.		Five.
Length	0.60	=	1.524
Height above axis of shank	0.875	=	2.222
Thickness	0.25	=	0.635
Diameter of eye	0.30	=	0.762
Links—Number of pieces	Ten.		Ten.
Length	2.10	=	5.334
Width	0.60	=	1.524
Thickness	0.125	=	0.317
Diameter of rivet holes	0.30	=	0.762
Distance between center and rivet holes	1.50	=	3.810
Flukes—Number of	Five.		Five.
Length	8.30	=	21.082
Greatest width	0.60	=	1.524
Lesser width	0.30	=	0.762
Width at point	0.10	=	0.254
Thickness	0.25	=	0.635
Diameter of rivet holes	0.30	=	0.762
Distance between rivet holes	2.05	=	5.206
Total length of shot and shank with flukes closed	23.50	=	59.689
Total length of shot and shank with flukes extended	24.60	=	62.483
Distance of center of gravity from base	5.00	=	12.700
Weight	18.218 + lbs.	=	8.264 kilos

ACTION.

The projectile is inserted in the gun point first, with the flukes closed and the line tied in the eye-hole of the shank. In this position the base

of the shot is toward the muzzle of the gun; the flukes partially enter the bore while the shank extends beyond the muzzle. In firing, the projectile describes the first part of its trajectory base foremost; the strain upon the shank being toward the rear, the flukes are kept closed; but, as soon as the projectile reverses, the tension on the line draws out the shank to the limit of its *play* in the base, spreading the flukes to their full extent. When the head of the shank reaches the bottom of the counter-bore in the base of the shot, the stop is thrown out by the action of the stop-spring and a square shoulder catches on the base and prevents the closing of the flukes. The latter may be opened and closed readily by hand. To close the flukes press the thumb upon the stop until the shoulder is disengaged, and then push in the shank gently till its head strikes the front end of the counter-bore.

USE.

When vessels are stranded the crews sometimes fasten a line or rope to a cask, spar, buoy, or raft, and heave it overboard, hoping that the wind and waves will throw it on the shore to be seized by persons there, thus establishing communication between the wreck and beach. It frequently occurs, however, that there is an inshore current that carries the floating object along parallel to the coast, in which case the object desired fails to be attained. This projectile was devised for the purpose of firing over the line thus paid out from the stranded vessel, so as to pass above that line at some point between the cask or buoy and the vessel, and then by hauling in the attached shot-line, the flukes grapple the ship's line, and enable the life-saving crew on shore to land the buoy and secure the line from the vessel. There are other uses to which it may be put that will readily suggest themselves to those familiar with the service.

Shot No. 2, Plate II, marked A 2.

This projectile only differs from No. 1 in having the body two inches shorter and the shank two inches longer than that shot, and in being of less weight. The details are given in the plate.

WEIGHT.

Weight	15.8125 lbs.	= 7.172 kilos.
Distance of center of gravity from base	3.875 inches	= 9.842 centimeters.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Partial longitudinal section of grapple shot with the flukes closed.
Fig. 2. Same, opened.
Fig. 3. Shank, showing lugs, &c.
Fig. 4. Section of shank showing relative position of lugs and method of attaching links.
Fig. 5. Side and rear elevations of base.
Fig. 6. Plan and side elevation of stop and spring.
Fig. 7. Plan and elevation of nut or shank-head.
Fig. 8. One of the pieces forming the link.
Fig. 9. Side and edge of fluke.

PLATE II.

See explanation of Plate I. The same figures are used in both to designate similar parts.

PLATE III.

The Lyle-Emery grapple shot closed.

PLATE IV.

The same shot open.

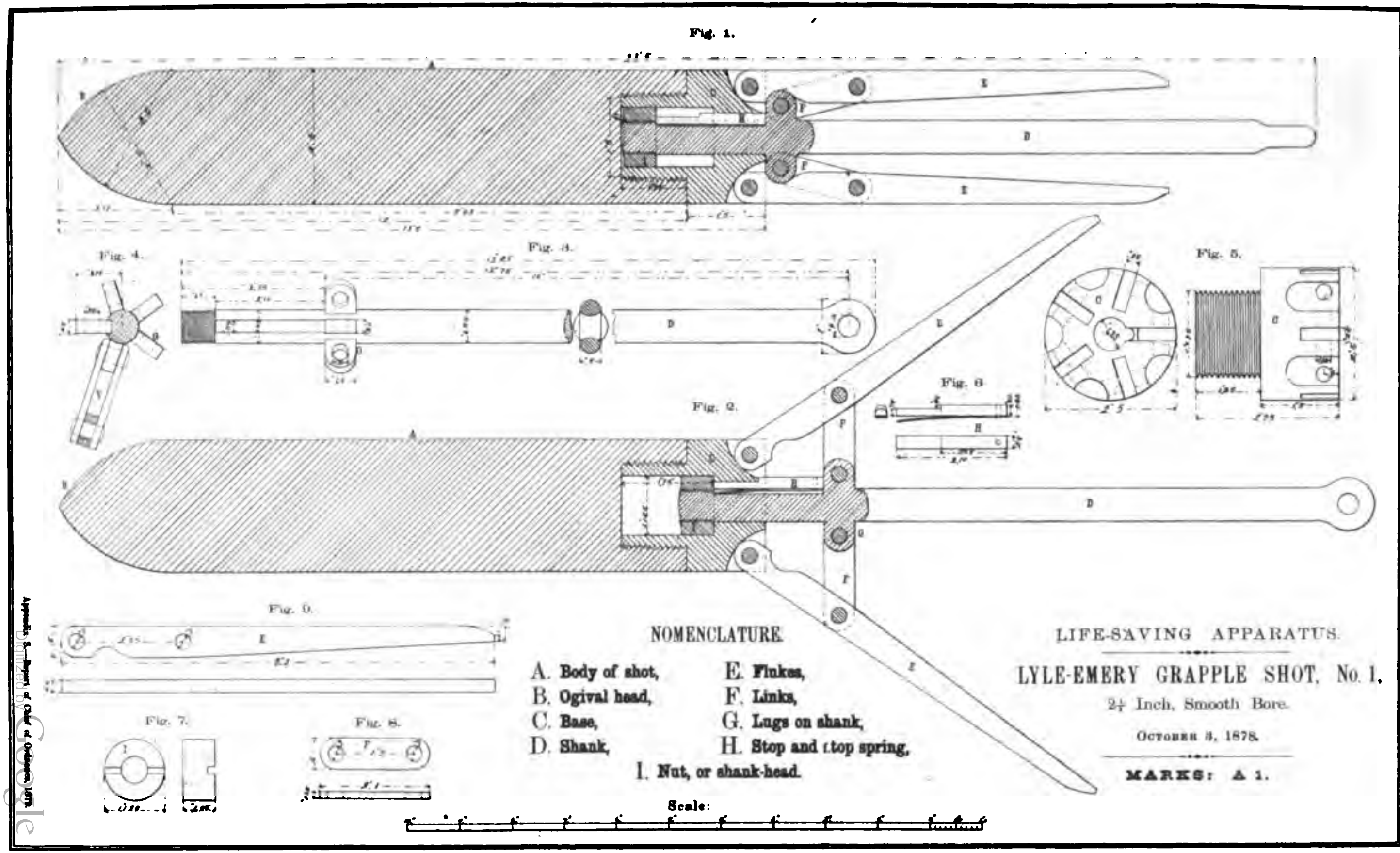
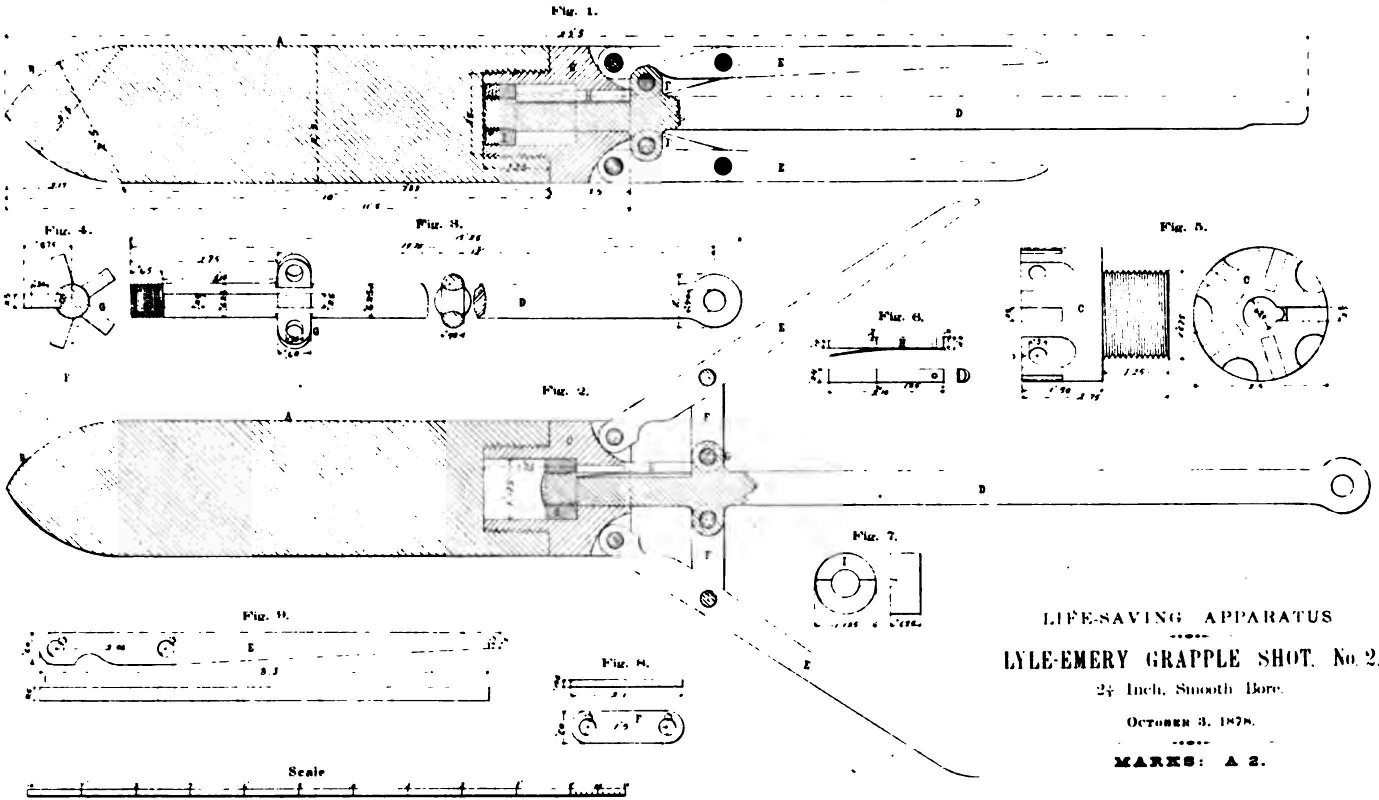


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
NOMENCLATURE.
A. Body of shot,
B. Ogival head,
C. Base,
D. Shank,
E. Flukes,
F. Links,
G. Lugs on shank,
H. Stop and stop spring,
I. Nut, or shank-head.
LIFE-SAVING APPARATUS.
LYLE-EMERY GRAPPLE SHOT, No. 1,
2¼ Inch, Smooth Bore.
October 8, 1878.
MARKS: A 1.
Scale:



LIFE-SAVING APPARATUS

LYLE-EMERY GRAPPLE SHOT. No. 2.

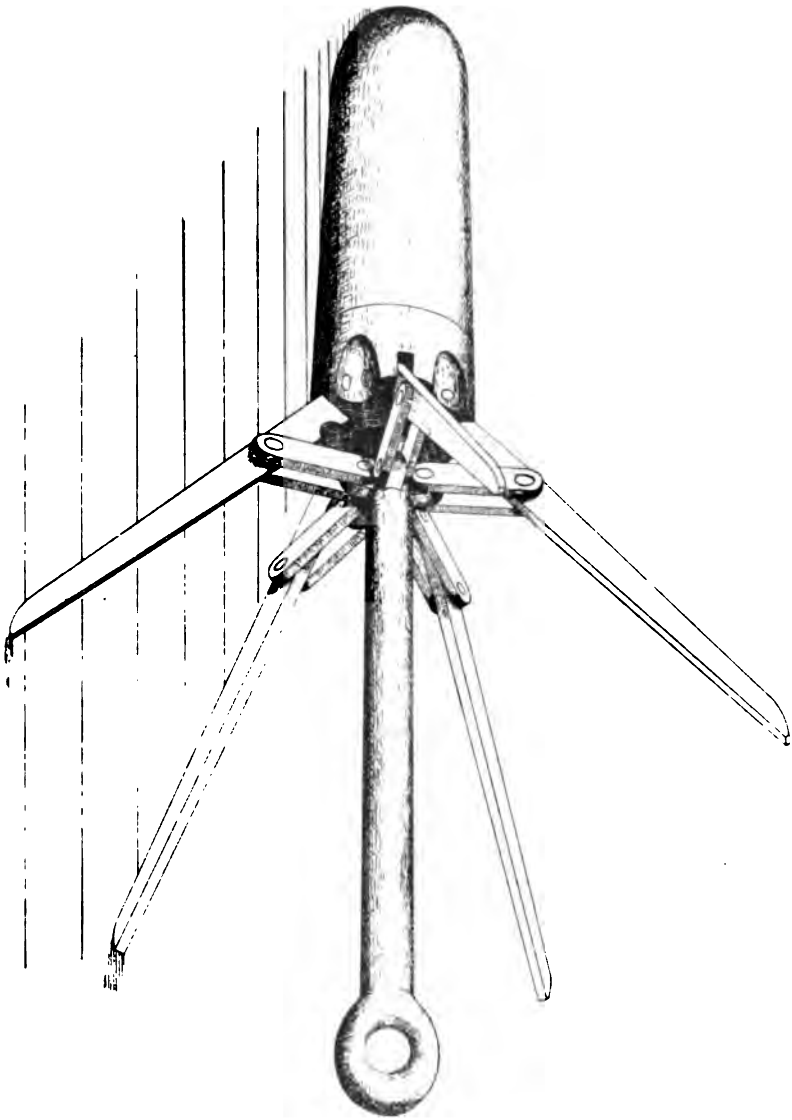
2¼ Inch, Smooth Bore.

October 3, 1878.

MARKS: A 2.

Appendix S.—Report of Chief of Ordnance, 1879.

LYLE-EMERY GRAPPLE SHOT, CLOSED.



LYLE-EMERY GRAPPLE SHOT, OPEN.

APPENDIX T.

DESCRIPTION OF THE LAIDLEY CAVALRY FORGE.

Col. T. T. S. LAIDLEY, Ordnance Department

(Seven plates.)

The cavalry board of 1874 recommended for the cavalry service, "to supply a want long felt," "the adoption of a traveling forge-cart, to be issued to each company of cavalry, for the purpose of carrying the blacksmith's bellows, fire-box, anvil, coal, blacksmith's tools, horse-shoes, nails, and iron; also for the purpose of carrying the extra ammunition, saddler's tools, and supply of leather for repairs of horse equipments." The cart was to be an open one, without cover or tail-board, and of such size as to give a stowage of 21.9 cubic feet for tools, coal, and materials, packed in boxes, and arranged for draught by two horses or mules, one in shafts and the other by his side or in front.

After the necessary strength to withstand the wear and tear of service, and the desired efficiency to do the required work, the next most important requisite for a forge for the cavalry is light weight, to enable it to move with rapidity.

Of late years the smith's bellows for blowing his fire has been gradually giving place, both in portable and stationary forges, to the rotary fan-blower, which has the advantage of giving a much better and steadier blast and occupying less space. These qualities fit it in an eminent degree for use in traveling forges and specially urge its claims for favorable consideration; but it was found on visiting shops where both systems were used, that the bellows were preferred by the workmen, and this arose on account of the monotonous and tiresome mode of working the fan-blower, which was done by a crank. This motion does not admit of the same change of position as that for blowing the bellows, but calls in play always the same muscles, and admits of little change or relief. It was clear that in order to make the introduction of the fan-blower a success other means of giving motion to it must be devised.* It was observed that sewing-machines and hand-lathes were successfully worked by Hall's treadle, which communicates motion always in the same direction by simply pressing the foot on the treadle, no matter in what position the fly-wheel may be; it has no dead centers. It was believed that if the blower were arranged to be driven by a lever worked by the hand—so as to enable the man to change his position and shift the work from one hand to the other, the sole objection to the blower would disappear and a better and more constant blast be obtained—the space occupied by it being less, the size and weight of the cart could be diminished.

A better disposition of the fire-pan was desirable, so as to obviate the necessity of breaking and forming the connection of the blast-pipe with

*In this connection I have to call your attention to the credit due to Mr. A. T. Brewer, of this arsenal, for the zeal he has shown and the intelligence that has guided it from the beginning to the completion of this work. He first brought to my attention the frequent use of fan-blowers for portable forges, and besides the silent ratchet, which is as effective as ingenious, there are other matters of detail of his arranging. Without his assistance I am sure the details of the forge would not be as complete as they now are.

the fire-pan whenever the forge was to be prepared for the march or for work. This was effected by making this connection permanent, and causing the fire-pan and blower to slide in and out of the body of the cart when required, or not, for use, like a table drawer. It was also deemed advisable to provide the body with a light wooden cover, the better to protect the contents of the boxes from rain and dust.

THE BODY—(Plates I and II.)

The body of the cart is composed of two sides and two middle sills of oak, diminishing in depth from the middle to either end. They are let into the axle body to which they are secured, the former by two under straps and the latter by two bolts. The side sills are rabbeted to receive the ends of the flooring boards, which are 0.5-inch ash, and connect the sills together. The rear end of each middle sill and its corresponding side sill is connected by a rear sill, and the end of the middle sill is braced by a plate-support hinged to the end of the cover. Runs for the saddler's box are riveted to the supports. The footboard is fastened to the sills by two bolts in each. The splinter-bar connects the front ends of the sills, which are held by one bolt in each. It projects beyond the body on the off side, and is strengthened by two iron braces. Four iron stays are bolted to each side sill, and the sides of the body, made of 0.5-inch whitewood boards, are riveted to them. The rear stays have projecting lugs with holes for the tail-rod. Corner irons are screwed to the front end of the body, which is cut down to the distance of one foot to form a seat for the driver. Two vertical partitions parallel to and in front of the axle form two compartments, one under the driver's seat and the other just in rear of it. This latter is further divided in the middle of its length by a vertical partition running crosswise.

The space between the middle sills in rear of the axles is not floored. The front half of this space is covered in by a thin boiler-plate inverted arch, closed at the front end, which is fastened to the axle body and secured to the top of the middle sills by the screws that hold the guide-plates. These latter direct the motion of the forge-frame in sliding in and out. The step is fastened to the side sill on the near side under the foot-board. A seat-rail is screwed to the top of the driver's seat at each end. Four stirrups are bolted to the splinter-bar, and two pintle-hooks and a shackle to the axle body, to secure the shafts in different positions, as required.

The anvil-rack is made of two pieces of angle-iron, secured at the front ends to the axle by two tap-screws, about which they move as a hinge. They are joined at their rear ends by a cross-piece, to which is riveted a hasp, its staple and plate being screwed to the rear sill. A brake, to regulate the motion of the cart in going down hill, is provided, and is operated by the driver's foot pressing against a lever just in front of the splinter-bar. Two props made of gas-pipe are hinged, one to the front and the other to the rear end of the body, and are held in position when traveling by spring catches operated by a wire rod ending in a ring at a convenient point.

The axle is let into the axle body and secured to it by the under straps, shackle, and bolts. Its under surface is in cross-section the arc of a circle.

The cover has a light frame composed of two rails, two ends of oak, slightly arched, and three ribs of ash, covered with .375-inch whitewood boards, sheathed with No. 25 sheet-copper. It is hinged to the body at

the rear end, and secured at the front by a hasp and staple for a padlock. A folding iron prop holds it in position when open. No tailboard is required. The coal-box, fire-pan, smith's and saddler's boxes fill the body and are held in place by the tail-rod, which is secured by a key and padlock.

The shafts are curved to give the horse greater freedom of motion. In the selection of the wood care must be taken to get such as has a corresponding curve in the grain, so as not to cut across it. The large end is provided with an iron shaft-eye by which to attach it to the axle body; that for the off shaft is bent to keep it away from the wheels so as to avoid the collection of mud on it. Eye-plates are riveted to the front ends to hitch the traces of the horse in front. The shafts may be shifted so as to admit of the cart being drawn either by two horses abreast or tandem. A whiffletree hooks in an eyebolt on the near end of the splinter-bar for draught when the horses are abreast.

The wheels are 57 inches in height, have sixteen spokes, bronze naves, and steel tires.

The anvil is securely attached to its block by means of a bolt passing through the latter. The head of this bolt has a screw-thread cut on it, on which the anvil-block base is screwed. This is a circular plate of wrought iron, and is required to give greater stability to the anvil when in use. It is carried in the fire-pan.

FORGE—(Plate III.)

The forge is composed of a box-shaped wrought-iron frame to which are securely riveted the fire-box, fan, and brackets for the necessary gearing. It is complete in itself, and may be used either in the cart or placed on trestles in a tent or shop. In the former case it slides on brass ways fastened to the middle sills, and is held in place by a locking-bolt, P, operated by the lever *t*. The fire-pan F is formed by adding a sheet-iron bottom with a large hole in the middle to one portion of the frame and riveting to it a circular cast-iron dish having in its center a seat for the tuyere and a connection for the blast-pipe. The bottom of the latter is movable and forms a door through which to clean out the ashes which may fall through the tuyere

The fire-pan has a sheet-iron double cover hinged to its rear edge, and forming, when open, a fire-back for the forge. A sheet-iron apron, hinged to the upper front edge of the fire-pan, closes in the cart when the forge is not in use and excludes the dust. The rotary fan D, Sturtevant's 0000 pressure blower, about twelve inches in diameter, is secured to the transoms S S by four bolts, and admits of a motion of 5-inch to the front and rear for the purpose of keeping the proper tension on the belt, which is effected by turning the screw R. The rotary fan requires, in order that it may perform its work to the best advantage, that it shall revolve rapidly. To attain the desired speed a system of gears and pulleys is necessary. Two wrought-iron brackets A A are riveted to the transoms; their bronze bushings form the bearings for three shafts, B, C, and G, the former two carrying each a wheel and pinion, and the latter the driving-wheel H, with teeth cut on the face and both edges; on the shaft G is placed the lever L, which carries two pawls working in the ratchets of the driving-wheel H. A simple device raises the pawls from the ratchets when not at work and prevents the clicking noise common to ratchets. A spiral spring attached to the short arm keeps the lever down ready for use; the brake handle is engaged in the link T and resting in the fulcrum K. A rotary motion is

given to the fan by pressing the lever down with the hand, continuing the pump-handle motion with a length of stroke to suit the pleasure or requirements of the workman, and greater rapidity till the desired motion is given to the fan; it is always in the right direction.

In the carts first built the driving-wheel and lever were different from that just described. The wheel had in-place of the ratchet a projecting rim, and the lever instead of the pawl had two bronze arms bearing two steel gibs embracing the rim; when the lever was raised the gibs caught the rim of the wheel and by their friction caused it to turn.

The silent ratchet was preferred on account of its positive action and the less accuracy of adjustment required for its satisfactory performance. The fulcra K K are riveted to the frame and have a hinge near their lower ends that they may be folded down on the fire-pan when not in use. The diaphragm M is riveted to the frame and closes against the fan protector, excluding the dust and dirt from the fan and gearing. A galvanized sheet-iron hood covers the gearing and protects it from accident; a pocket in the right side is made to carry the brake handle.

BOXES—(Plate IV.)

The boxes are made of .5-inch whitewood boards dovetailed and securely held together by small screws and corner irons; one end of each is covered with sheet-iron to protect it from the effect of the smith's fire.

The smith's tool-box has three horizontal partitions in it, made of 1-inch ash boards; a compartment for holding the saddler's bags, or small stores, is made in the front part of the box on top; access is had to it when the cover is raised. The rear end of the box is closed by a door covered with sheet-iron, hung on hinges; it is secured when in the cart by the tail-rod, but has also a padlock for security when the box is removed from the cart.

The coal-box corresponds in construction with the tool-box except it has no horizontal partitions, but has a sliding door of iron, in the rear end, through which the coal is taken out as required; this door has a handle which is secured by the tail-rod. The box is filled with coal from the top, first having been partly pulled out to the rear; it will contain one hundred and sixty-five pounds of coal.

The saddler's box is of an irregular shape, with deep sides to contain the leather and thus utilize all available space about the forge; it has a cover hinged at the rear end and is secured by a chest lock; it slides when in the cart on iron runs, and is held by a hasp and staple to the end of the cover, secured by a padlock; it may be removed or retained in the cart at pleasure, independently of the other boxes.

The shoeing-box is the same as that for the field-forge except in length, the former being one-half inch shorter than the latter; it is carried on the fire-pan cover. The compartment under the driver's seat is for carrying the saddler's horse and clamp; the door in front closes against an iron rabbet and is held by two spring bolts, one of them secured by a padlock. The compartment for spare ammunition is secured by a sliding bolt and staple with a padlock.

REMARKS.

When the forge is packed for traveling, the materials, tools, and implements are all under lock and key and not liable to be lost or stolen.

The capacity of the boxes for storage is greater than that asked for by the board by 1.6 cubic feet.

The time required to prepare the forge for work or for transportation is not more than a minute, and the latter can be performed though the fire-pan may be greatly heated. The blast is strong enough to raise the tuyere-plate, weighing four pounds, from its seat, and a baggage-wagon axle may be brought to a welding heat in its fire. It has been found to meet all the requirements of the service, and has furnished the conveniencies for keeping shod for five months a wagon train of 750 horses and mules.

It is believed that the advantages gained by having the boxes removable from the body is not commensurate with the expense and additional weight that it necessitates, and it would be better to make them permanent fixtures to the cart.

To use the forge.—To prevent the cart from tipping over, chock the wheels in front and rear, and let down both props by pulling the handle-rings in front and rear. Unlock and take the key out of the end of the tail-rod; withdraw it. Let down the forge door and take out the shoeing-box. Grasp the hasp of the forge door with the right hand, insert the middle finger of the left hand in the handle of the locking-bolt; draw out the forge, pulling both hands toward the body; as soon as the forge has moved, let go with the left hand, continuing the action with the right till the locking-bolt stops it. Raise the fulcrum to a vertical position. Unlock and turn the anvil-hasp; seize the anvil-block with both hands; draw it out till the anvil rests near the end of the slide; take the anvil-plate from the fire-pan, screw it on the end of the block, and place the anvil four feet in rear of the cart and six inches to the left of the left wheel; withdraw the brake-handle from its pocket, hook the end in the link, and enter the handle in the slot in the fulcrum on the right, if the smith have a helper; on the left if he have none. Bear down on the handle gently at first, raise it a foot and bear down somewhat harder, increasing the pressure as the fan gains speed, continuing this pumping motion, and varying the rapidity of the stroke according to the amount of blast required.

To remove the forge from the cart.—Place two trestles parallel to each other, 16 inches apart; raise them to a height of 2 feet 8 inches. Two men, one on each side of the forge, take hold of it; one pulls the handle of the stop-bolt, and both draw the forge to the rear and place it lengthwise on the trestles. Take out the smith's chest and coal-box in the same way and place them in convenient places.

The saddler's chest may be taken out or left in the cart after the others have been removed.

To pack the forge for traveling, proceed in the inverse order to that already described.

To load the cart.—Draw the coal-box part way out to the rear; put in the coal from the top; push it well to the front end of the box. Take the saddler's horse to pieces by unscrewing the screws in the legs, clamp, and rounds; pack them and the saddler's clamp in the box under the driver's seat. Distribute the rest of the load so that the horse in the shafts shall not have too great a weight on his back and shall work to the best advantage.

Care and preservation of the forge.—Keep the wheels clean and the journals well oiled. See that the oil-cups always have oil in them. Preserve the belt soft and pliable by oiling it. If it become loose and slip on the pulley, slacken the set-screws which hold the fan, in front and rear; draw the fan back by means of the tangent screw; tighten the set-screws. Keep up just sufficient tension on the belt to prevent it from slipping. Before fording a deep stream remove the belt from the pulley

to keep it from getting wet; after passing the stream wipe the machinery dry and oil it.

To prepare a new belt, use thin, soft leather; wet it thoroughly, stretch it, and nail it to a board till dry. Sew the ends together after it has been cut to the proper length. Oil it well.

DIMENSIONS.

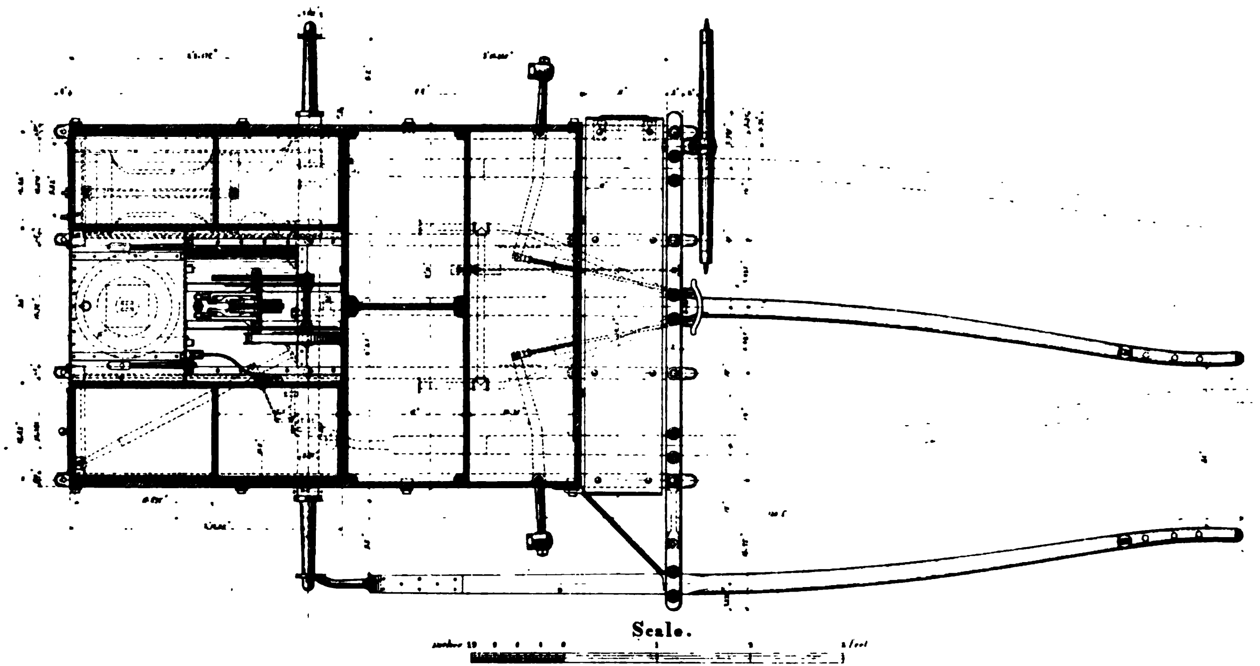
	Inches.
Width of track of wheels	62
Whole length of axle	83.25
Width of body	47
Length of body	66
Length of cart, including shafts	154
Height of wheel	57

WEIGHTS.

	Pounds.
One wheel	108
Shafts (both)	47
Anvil-block and base	106
Forge, hood, &c	145
Tool-box, empty	55
Coal-box, empty	63
Coal-box, filled with coal	228
Saddler's box	44
Whiffletree	4
Tuyere	4
Anvil base	7.5
Cart (complete), empty	1,075

LAIDLEY CAVALRY FORGE.

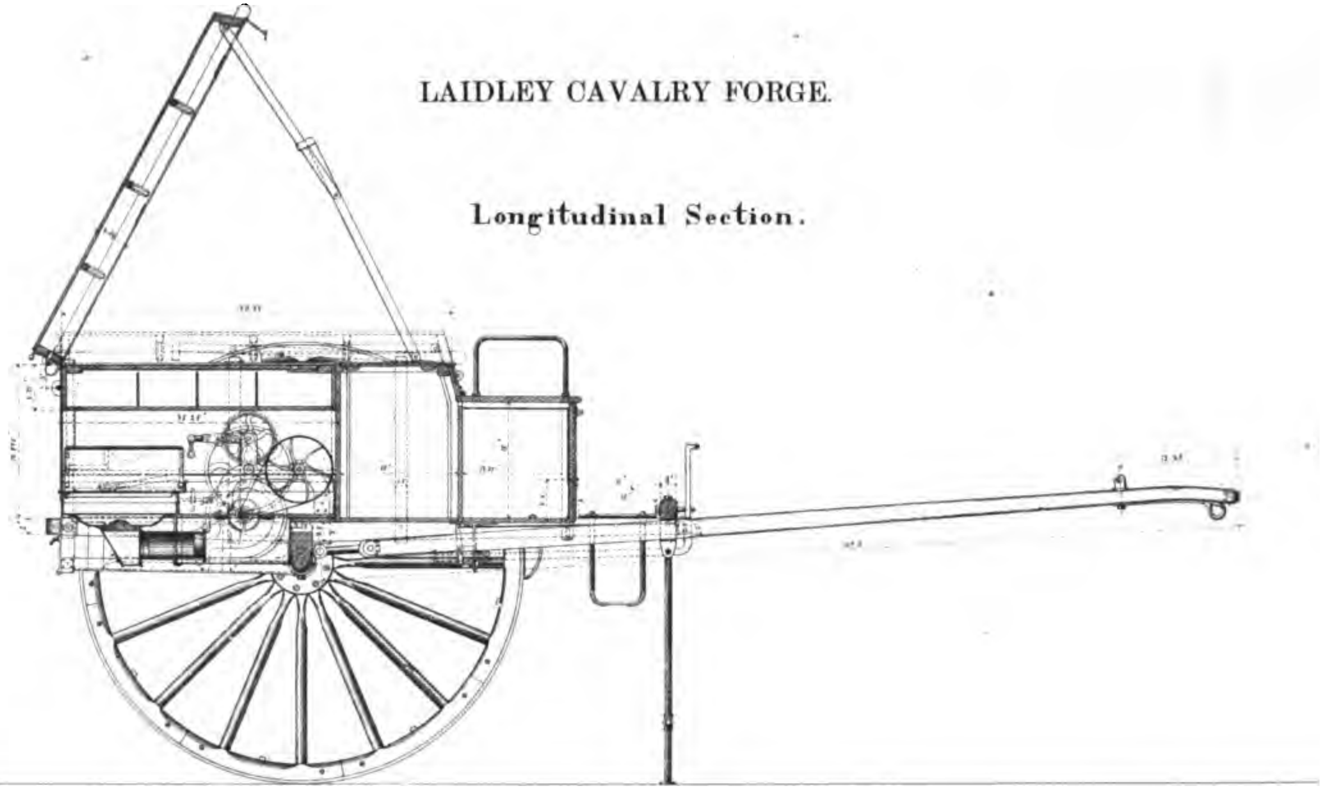
Horizontal Section.



Scale.

LAIDLEY CAVALRY FORGE.

Longitudinal Section.

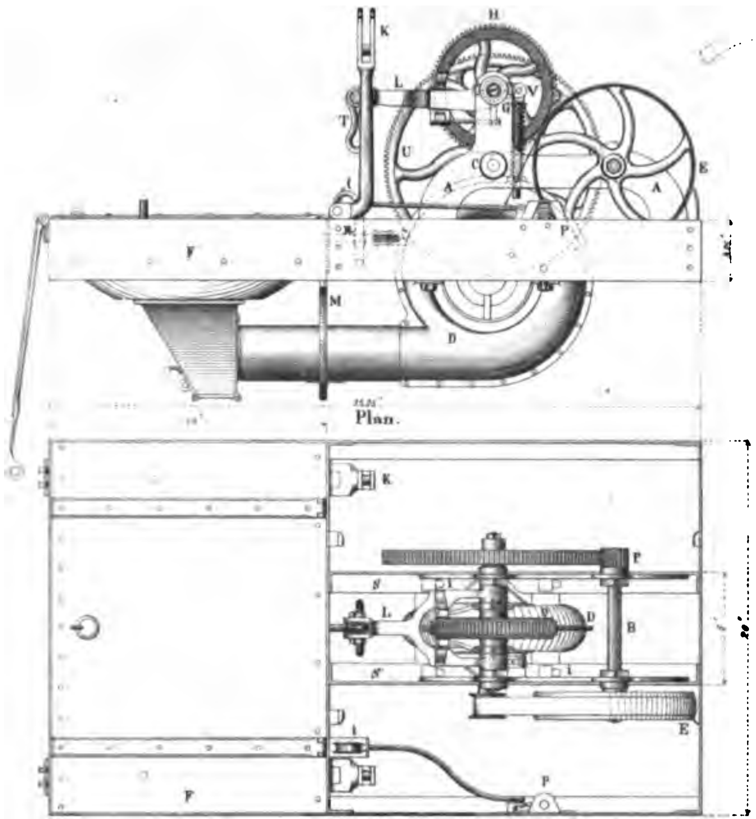


Scale.

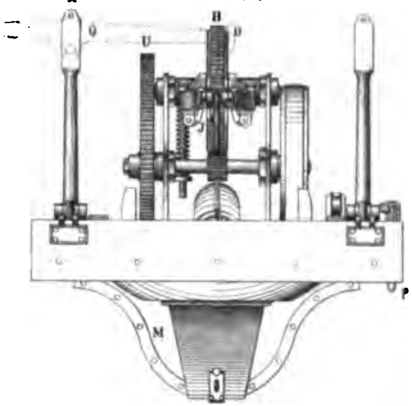
inches 12 9 6 3 0 1 2 3 feet.

Elevation.

Plan.



End view.

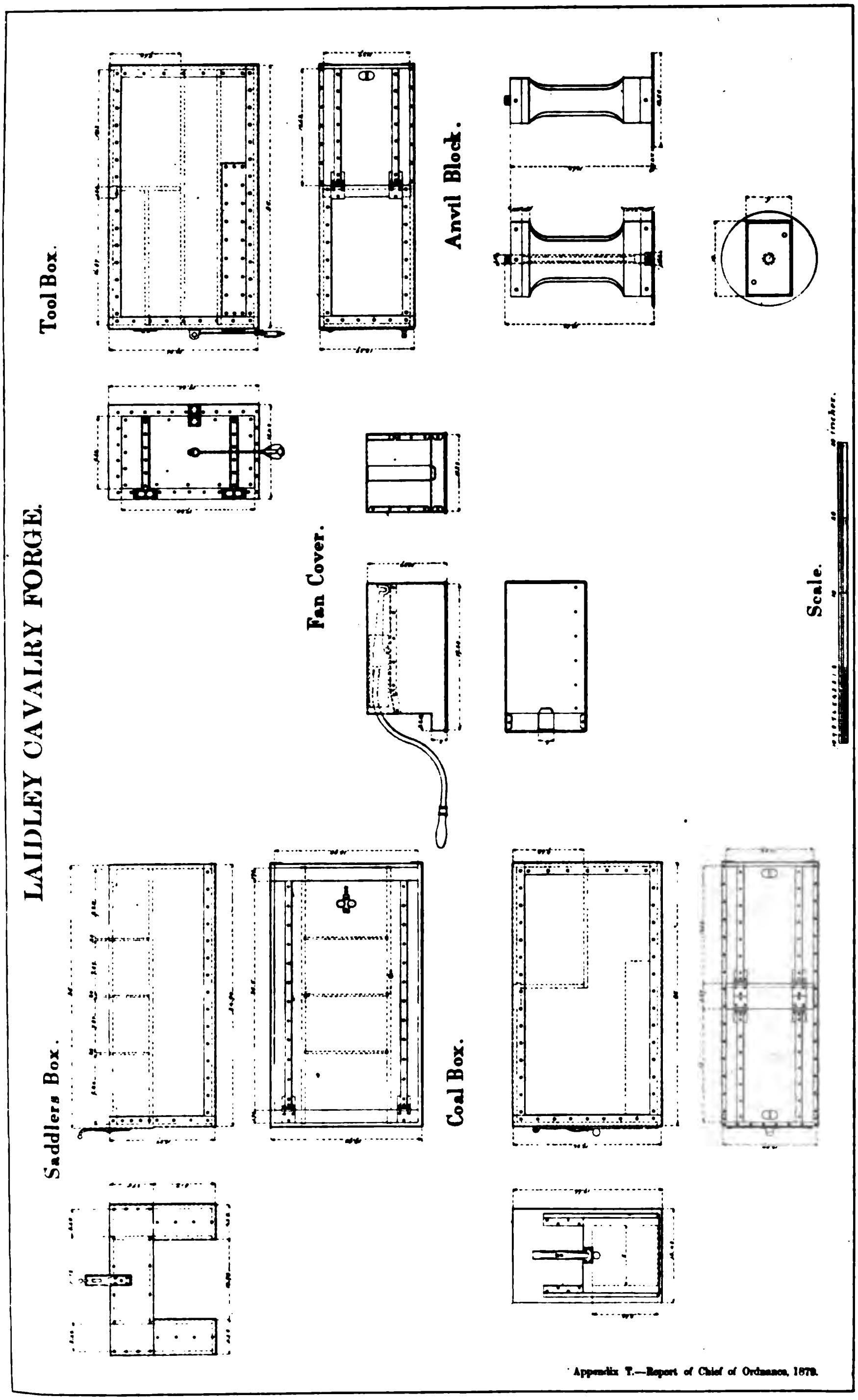


LAIDLEY CAVALRY FORGE.

A. T. Brewer's Ratchet.

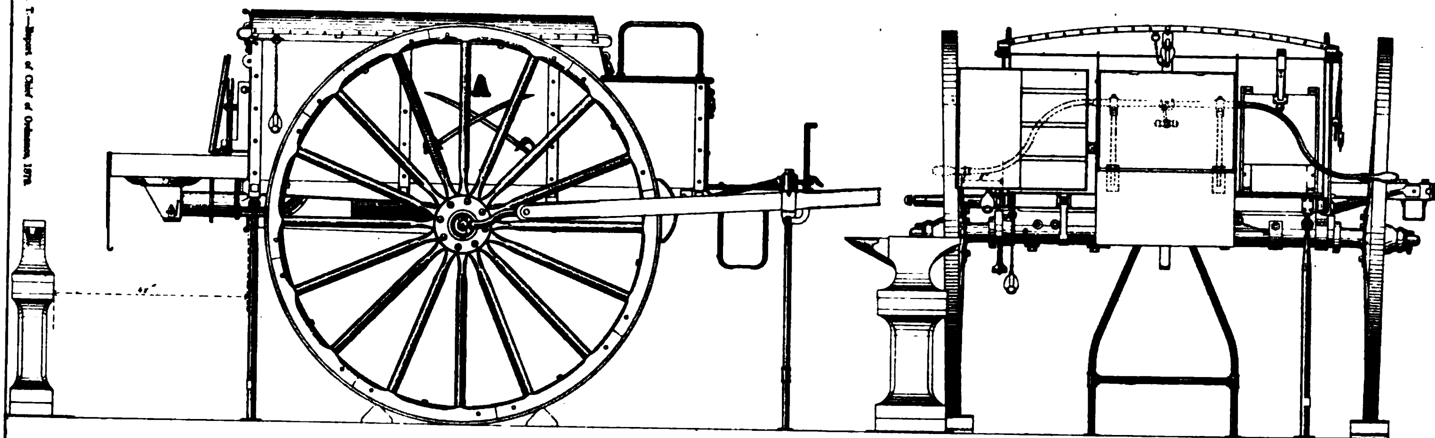
Scale.

Inches


LAIDLEY CAVALRY FORGE.
Tool Box.
Anvil Block.
Fan Cover.
Scale.
inches
Saddlers Box.
Coal Box.

LAIDLEY CAVALRY FORGE

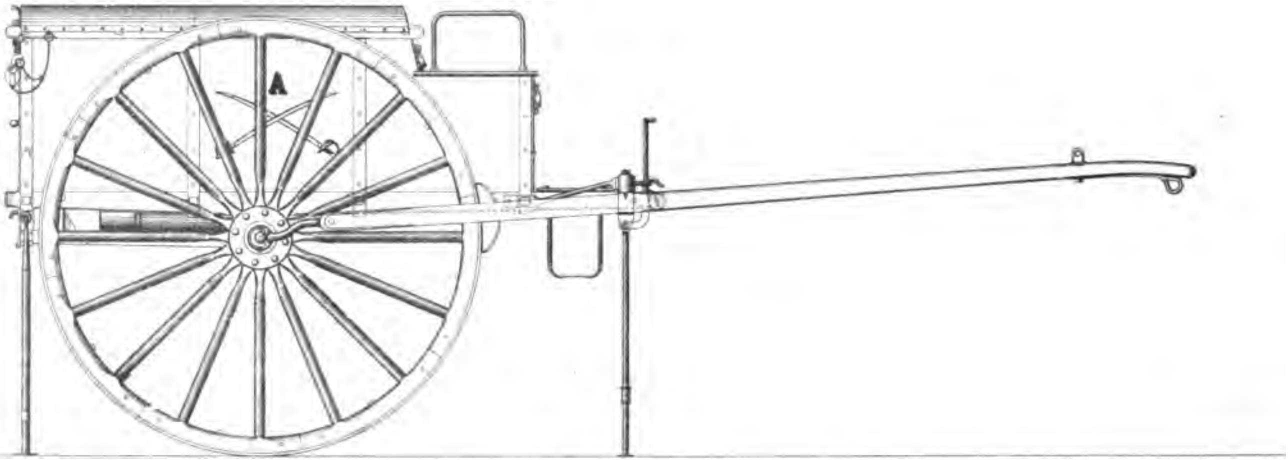
ready for use.



LAIDLEY CAVALRY FORGE.

for 2 Horses abreast.

Side Elevation.

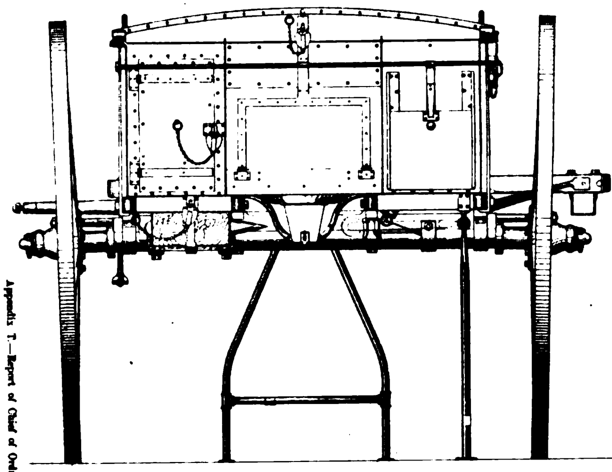


Scale.

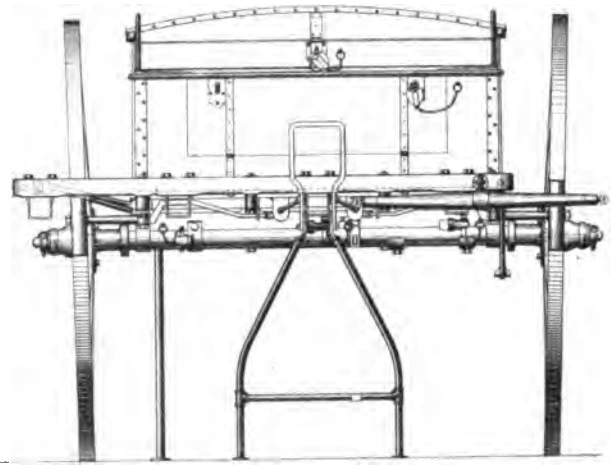
inches 12 . . . . . 0 1 2 3 feet.

LAIDLEY CAVALRY FORGE.

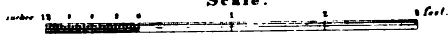
Rear Elevation.



Front Elevation.



Scale.



APPENDIX U.

SWOLLEN BARRELS IN SERVICE SMALL-ARMS.

Indorsement upon a letter written by Capt. J. H. Smith, Nineteenth Infantry, U. S. Army, to the Chief of Ordnance, under date of August 12, 1879.

NATIONAL ARMORY, *September* 6, 1879.

Respectfully returned to the Chief of Ordnance.

Every rifle and carbine made at this armory is fired at least five times with the service cartridge besides three proof charges, viz: 280, 250, and 80 grains of powder and a heavy bullet, respectively. There have besides been many thousand cartridges fired in testing experimental guns and cartridges. In all more than 1,000,000 of cartridges have been fired since 1870, and in no instance, so far as can be ascertained, has there ever occurred the bursting or swelling of a barrel at or near the muzzle. From these facts I think it may be safely inferred that a swollen or burst muzzle in service must result from some obstruction.

A report of a trial made by Captain Greer at this armory, herewith inclosed, shows the effect of firing the service rifle with different kinds of obstructions placed in the bore at the muzzle.

J. G. BENTON,
Colonel Ordnance, Commanding.

NATIONAL ARMORY,
Springfield, Mass., September 5, 1879.

SIR: In accordance with your instructions to ascertain, if practicable, from what causes the swelling of the muzzle of the service rifle results, I have the honor to submit the following report: Two condemned barrels were taken at random from a lot turned in from the field. Eight or ten rounds were fired from one of them, rags of various sizes having been inserted in the bore a little below the front sight, without affecting the barrel the slightest. Sand next having been inserted in the muzzle, the barrel was shaken so as to remove all but a few grains which adhered to the fouling; the piece was then fired. This was repeated several times without swelling the muzzle. The barrel was then run into wet sand and the bore nearly filled for about an inch and a half. After firing in this condition the barrel was found swelled at the muzzle precisely like those that have been received from time to time from the field. Several pine plugs, from six to eight inches in length, were then prepared of a size to fit the bore closely. The second barrel was fired twice with the plugs driven in dry about one-half their length, twice driven in wet, and twice driven in dry, but afterward swelled by steam both inside and outside, without injury to the barrel. The inclosed air probably forced the plugs out before the bullet reached them. A plug was then split in two to represent a broken tompion, the air being free to pass by the plug. It was thought the bullet might wedge on the remaining side of the plug, but the barrel was found uninjured after the shot was fired. Occasionally the cup-anvil of the Frankford service shell has been found in the

barrel after firing. It was thought possible that one of these might become wedged in the barrel and cause the swelling. To test this question an anvil was driven down squarely across the barrel, just opposite the front sight. The piece was then fired without injury to the barrel. A second anvil was driven down to the same position, but obliquely to the axis of the bore. No damage resulted from the firing. A long wad of cotton-waste was then wet and rolled into a spiral and forced down the barrel several inches by the ramrod. The piece was then fired, when the barrel was found swelled a little beyond the wad, which was probably carried forward a few inches before the bullet wedged upon it.

It would seem from these trials that swelling at the muzzle is caused chiefly by sand at that point, rags, &c., being blown out; but that rags lower down may cause a swelling at some point between their position and the muzzle; that the use of tompions is less hurtful than heretofore supposed; and finally, that swelling, not being easily produced, is the result of negligence in not seeing that the bore is free from obstructions.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A.

To the COMMANDING OFFICER,
National Armory.

APPENDIX V.

REPORTS ON INDIAN ARMS.

Capt. JOHN E. GREER, Lieuts. D. A. LYLE and ROGERS BIRNIE, JR., Ordnance Department, and Master Machinist S. W. PORTER, National Armory.

(Ten plates.)

NATIONAL ARMORY, *Springfield, Mass., July* 27, 1879.

Of the large number of arms received at this armory from the various Indian agencies, the larger portion of which were muzzle-loaders—some even having flint-locks—four were turned over to the board as being either the most powerful or the most rapid firing guns in the collection. These were as follows:

No. 1.—Sharp's breech-loading target rifle, cal. .44, center fire; old model; set trigger. Weight of gun 12 pounds 12 ounces; tip-stock partly gone; original weight probably 13 pounds. Barrel heavy, octagonal; length 30 inches. Chamber bottle-shaped; number of grooves, 6. Twist of rifling uniform; rifling freed out 1¼ inches beyond shell chamber. Rear sight, "buckhorn;" slide on leaf so loose as to indicate that it could not have been used. Front sight bright but rough; probably made from a silver quarter-dollar.

No. 2.—Same as above, except that the barrel was but 22.9 inches long; weight 9 pounds 6 ounces. Rear sight in good condition; front sight so loose as to affect accuracy of fire unless great care was used.

A cast in sulphur having been taken of the chambers of these guns, it was found the ammunition required was that known as "Sharp's long range." Weight of powder 77 grains; weight of ball, patched or grooved, 470 grains.

No. 3.—Winchester repeating (17 shot) rifle, cal. .44; rim fire; model 1866. Octagonal barrel; length 24 inches. Weight of rifle 9 pounds.

No. 4.—Same in all respects as No. 3. Rear sight leaf broken off. Ammunition: weight of powder 26 grains; weight of ball 202 grains.

The ammunition for all these guns was purchased at the Winchester Repeating Arms Company's Armory, New Haven, Connecticut.

The barrels of these guns having been thoroughly cleaned were examined and found to be in good order.

On account of the small charge carried by the Winchester repeater it was tested in comparison with the Springfield carbine for accuracy, rapidity and accuracy combined, power—as shown both by penetration in white pine and computed energies—and initial velocity. Similar comparisons were made between the Sharp's and Springfield rifles.

The results are given in the following tables:

1. *Weights, &c.*

Arm.	Weight of arm.	Length of barrel.	Weight of powder-charge.	Weight of ball.
		Inches.	*Grains.*	*Grains.*
Springfield rifle	9 pounds, 2 ounces	32.6	70	405
Sharp's rifle, No. 1	12 pounds, 12 ounces	30	77	470
Sharp's rifle, No. 2	9 pounds, 6 ounces	22.9	77	470
Springfield carbine	7 pounds, 12 ounces	22	55	405
Winchester repeating rifle	9 pounds	24	26	202

2a. *Accuracy.*

Arm.	300 yards. Mean horizontal deviation.	300 yards. Mean vertical deviation.	300 yards. Mean absolute deviation.	500 yards. Mean horizontal deviation.	500 yards. Mean vertical deviation.	500 yards. Mean absolute deviation.	600 yards. Mean horizontal deviation.	600 yards. Mean vertical deviation.	600 yards. Mean absolute deviation.	800 yards. Mean horizontal deviation.	800 yards. Mean vertical deviation.	800 yards. Mean absolute deviation.	1,000 yards. Mean horizontal deviation.	1,000 yards. Mean vertical deviation.	1,000 yards. Mean absolute deviation.
Springfield rifle	....	....	....	5.3	9.4	10.8	....	....	....	13.2	15.5	20.3	6.3	19.3	20.4
Sharp's rifle, No. 1*	....	....	....	10.7	8.8	13.9	....	....	....	18.5	27.8	33.4	22.3	7.7	23.6
Sharp's rifle, No 2†	....	....	....	9.9	10.2	14.2	....	....	....	39.2	8.5	40.1	14.3	30.2	33.4
Springfield carbine	5.5	2.3	6	....	....	....	15.5	7.3	17.1	....	....	....	....	....	....
Winchester repeating rifle	7.1	5.2	8.8	....	....	....	12.4	15	19.5	....	....	....	....	....	....

* One shot at 1,000 yards missed target twelve feet square.
† One shot at 500, six at 800, and four at 1,000 yards missed the target.

2b. *Accuracy.*

(As recorded by Creedmoor system.)

Arm.	300 yards. Possible 50.	500 yards. Possible 50.	600 yards. Possible 50.	800 yards. Possible 50.	1,000 yards. Possible 50.
Springfield rifle	....	44	....	38	33
Sharp's rifle, No. 1	....	38	....	23	4
Sharp's rifle, No. 2	....	32	....	2	9
Springfield carbine	44	....	38	....	....
Winchester repeating rifle	39	....	23	....	....

3. *Rapidity with accuracy.*

Arm.	200 yards range.—Creedmoor record. Number of shots in one minute.	Number of shots in two minutes.	Number of hits; target 12 ft. square.	Number of points.	Number possible.
Springfield rifle	15	....	15	35	75
Sharp's rifle, No. 1	12	....	11	20	60
Sharp's rifle, No. 2	10	....	10	17	50
Springfield carbine	....	29	29	78	145
Winchester repeating rifle	....	33	33	57	165

The Winchester magazine—capacity 17 cartridges—was loaded before commencement of test. All other cartridges were disposed at will on a table.

4. *Penetration.*

Arm.	200 yards. Mean of 5 shots.	300 yards. Mean of 5 shots.
Springfield rifle	—— inches in white pine	12.65 inches in white pine.
Sharp's rifle, No. 1	—— inches in white pine	16.87 inches in white pine.
Sharp's rifle, No. 2	—— inches in white pine	15.25 inches in white pine
Springfield carbine	10.05 inches in white pine	—— inches in white pine
Winchester repeating rifle	5.05 inches in white pine	—— inches in white pine

5. *Velocities.*

Arm.	No. of shot.	Velocities by— Le Boulongé chronograph.	Benton's electro-ballistic.
Springfield rifle	1	1336.2	1339.4
	2	1339.7	1345.3
	3	1353.4	1354.2
	4	1335.7	1339.4
	5	1349.5	1354.1
Mean		1342.9	1346.5
Mean by both machines		1344.7	
Sharp's rifle, No. 1	1	1243.1	1247.9
	2	1244.6	1245.4
	3	1258.3	1263.2
	4	1263.7	Wire not cut.
	5	1243.1	1245.4
Mean		1250.7	1250.5
Mean by both machines		1250.6	
Sharp's rifle, No. 2	1	1192.7	1199.9
	2	1210.3	Wire not cut.
	3	1184.8	1191.1
	4	1200.5	1199.9
	5	1184.8	1191.1
Mean		1194.6	1195.4
Mean by both machines		1195	
Springfield carbine	1	1128.5	1128.9
	2	Wire not cut.	1128.9
	3	1133.9	1135.1
	4	1110.8	1116.5
	5	1128.0	1128.9
Mean		1125.3	1127.7
Mean by both machines		1126.5	
Winchester repeating rifle	1	1181.4	1183.4
	2	1171.1	1172.1
	3	1166.2	1167.5
	4	1148.6	1150.0
	5	1164.2	1165.2
Mean		1166.3	1167.6
Mean by both machines		1167	

6. *Energies.*

Arm.	Weight of powder.	Weight of ball.	At muzzle. Velocity.*	At muzzle. Energy.	At 300 yards. Velocity.†	At 300 yards. Energy.
	Grains.	*Grains.*	*Feet.*	*Ft.-pounds.*	*Feet.*	*Ft.-pounds.*
Springfield rifle	70	405	1344.7	1626.5	923.9	769.9
Sharp's rifle, No. 1	77	470	1250.6	1633.7	929.4	901.7
Sharp's rifle, No. 2	77	470	1195	1490.7	899.6	844.7
Springfield carbine	55	405	1126.5	1141.5	820.6	605.8
Winchester repeating rifle	26	202	1167	611	671.2	202.1

*Instrumental. †Computed.

Examination of the foregoing tables shows conclusively that the Springfield rifle is more accurate than the Sharp's rifles at all ranges at which they were tested. At the longer ranges the short barrel, No. 2, bears no comparison to the Springfield. One thousand yards was the extreme limit at which the Sharp's with long barrel could be fired unless special sights were prepared for it. As this board was required to test these arms in the condition received, and as used by the Indians, this was, of course, inadmissible. It may be said briefly that the long-barrel Sharp's is a more powerful arm than the Springfield rifle, its barrel alone weighing more than the Springfield complete. It is not, however, a practicable service arm on account of its great weight, 13 pounds, and that of its ammunition. While this one gun is undoubtedly capable of firing at longer range than the Springfield, this very quality has been ignored by the Indians, as may be seen by examining its sight and those of other arms received at this armory from the Indian agencies. Both the Sharp's have had peep-sights, and the longer one probably a telescopic sight, judging from the slots in the barrel. All of these have been removed. Evidently the Indians did not desire to waste their ammunition (which they probably obtained with more or less difficulty) at long ranges.

In nearly all the other arms referred to, the sights are adapted to short range, only where the trajectory is very flat. In this respect, owing to its lighter bullet and higher velocity, the Springfield is superior to either of the Sharp's.

The Springfield carbine, with its cartridge containing but 55 grains of powder, is, of course, less powerful than the short-barrel Sharp's, but by using the rifle cartridge it may be brought very nearly to a par with it, and with much less weight. Compared with the Winchester repeater it will be seen that it is not only more accurate and powerful, but that it is nearly as rapid a firing arm when the time is extended so as to necessitate the use of other cartridges than those in the magazine.

The ability to rapidly empty the magazine is desirable, but it should be combined with more power than this gun possesses to make it especially valuable.

Report of a board composed of First Lieut. D. A. Lyle, Ordnance Department, and Master Machinist S. W. Porter, which convened at the National Armory August 2, 1879, upon a lot of small arms captured from the hostile Sioux and Cheyenne Indians. Approved by Col. J. G. Benton, Commanding the National Armory.

The commanding officer of the National Armory submitted to the board for its examination a lot of arms captured from the Sioux and Cheyenne Indians, that had been shipped to this place from Cheyenne, Wyoming Territory, by order of Capt. J. W. Reilly, Ordnance Department, Chief Ordnance Officer of the Military Division of the Missouri.

The board then proceeded to examine and prepare the following lists of the said arms:

TABLE I.

BREECH-LOADING ARMS.

Springfield carbines. (*Caliber* .45, *model* 1873.)

Number.	Number on receivers.	Breech system in working order or not.	Condition of lock.	Stock. Condition of.	Stock. If broken, where.	Condition of front sight.	Parts missing.	Remarks.
1	1196	Yes	Good	Broken	Small	Good		
2	3146	do	do	do	do	Badly worn		No ejector-spring.
3	3197	do	do	Badly worn	do	Replaced	Swivel-bar	No ejector-spring; front sight replaced by a piece of brass.
4	17485	do	Fair	Broken	Below small	Filed thin	Butt-plate	No ejector-spring; hinge-pin arm broken. Stock appears to have been run over by a loaded wagon.
5	17940	do	do	do	Small	Worn		
6	18137	do	do	do	do	Good	Leaf broken off sight	Extractor-slot "set down."
7	18141	do	do	do	do	Worn		Rawhide band holds stock together.
8	18202	No	No lock			Worn-out	Stock, breech-block, lock, and sight leaf.	Headless copper shell rusted in chamber.
9	20498	Yes	Fair	Broken	Small	Good	Band, rear sight, side screw, guard, and butt of stock.	
10	21573	do	do	do	do	do		Rawhide strap around small of stock.
11	21669	do	do	Worn		Worn		New leaf put in rear sight; stock, a model '66 altered; no ejector-spring.
12	33155	No	do	do		Part of nickel coin put in.	Breech-block, extractor, ejector-spring, and spindle and hinge-pin.	Ears of receiver broken off; receiver cracked in angle under ears on both sides.
13	33815	Yes	Disabled	Broken	In front of guard	Worn		Barrel split at muzzle.
14	34723	do	Fair	Cracked		do	Band	Set-screw put in to make a hair-trigger; arm has been run over by a wagon.
15	36442	do	Fair; hammer bent.	Piece broken out on left of receiver.		Good; put in		Barrel burst at muzzle.
16	39253	do	Fair	Broken	Small	Good	Butt-stock	
17	42259	do	Fair; 3-notch tumbler.	do	do	Worn		Rawhide band at small of stock; ejector-spring gone; extracts, but does not eject shell.
18	Number effaced by filing.	do	Fair	Cracked		do	Butt-plate	Stock cracked on left side.
19	do	do	do	Worn		Put in and filed thin.	Butt-plate, swivel bar and ring; rear sight base cut away.	

TABLE II.

Springfield carbines. (Various calibers and models.)

Number.	Model.	Caliber.	Breech system in working order or not.	Condition of lock.	Stock. Condition of.	Stock. If broken, where.	Parts missing.	Made from rifle by cutting off the barrel.	Remarks.
		"							
1	'66	.50	Yes	Good	Broken	Small		Yes	Front sight put in; rawhide strap around small of stock.
2	'66	.50	do	Fair	Worn		Butt-plate	do	Barrel one foot long.
3	'66	.50	do	do	do		do	do	
4	'66	.50	do	do	do		do	do	No front sight.
5	'66	.50	do	do	do		Butt-plate and swivel	do	
6	'66	.50	do	do	Broken	Small	Swivel	do	Buckhorn rear sight and front sight put on.
7	'66	.50	do	do	do	Right side	Butt-plate	do	Improvised thumb-piece.
8	'66	.50	do	do	do	In front of receiver.	do	do	
9	'66	.50	do	do	do	Under receiver	do	do	Buckhorn sight and large front sight put on.
10	'66	.50	No	do	Worn		Cam and thumb-piece; rear sight	do	Barrel 8″ long; tip-stock sawed off.
11	'66	.50	Yes	do	do		Butt-plate	do	
12	'66	.50	do	do			do	do	
13	'66	.50	do	do	Used up		do	do	
14	'66	.50	do	do	Worn		do	do	New front sight.
15	'66	.50	do	do	do		do	do	Buckhorn sight on receiver strap.
16	'66	.50	No	Useless	Broken		Breech-block and lock	do	
17	'68	.50	Yes	Fair	do	Left of guard		do	Front sight put in.
18	'68	.50	No	do	Cracked		Hinge-pin, ejector-spring and spindle, extractor and sights.	do	Number on receiver 32261.
19	'68	.50	Fair	do	Shaved down		Butt-plate	do	Guard-plate put on
20	'68	.50	No	do	Broken badly		do	do	Receiver broken under ears. No. 5283.
21	'68	.50	Fair	do	Broken	In front and rear of receiver.	Butt-plate and leaf	do	
22	'68	.50	Yes	do	do	In front of receiver.		do	No. 13203.
23	'68	.50	do	do	Worn			do	New guard
24	'68	.50	do	do	do		Butt-plate and swivel	do	
25	'68	.50	do	do	do		Ejector-spring	do	No. 33149.
26	'68	.50	Fair	do	do		Butt-plate and front sight	do	
27	'68	.50	do	do	do		Butt-plate	do	
28	'70	.50	do	do	Broken	Small	do		Brass front sight.
29		.58	No	do	Worn		do	do	Rack-spring broken. [Allin model.]
30		.58	Fair	do	do			do	New front sight. [Allin model.]

TABLE III.

Winchester and Henry rifles and carbines (using rim-fire metallic cartridges).

No.	Arm.	Caliber.	Shape of barrel.	Breech system in working order or not.	Condition of stock.	Remarks.
		"				
1	Henry	.42	Octagonal	Yes	Worn	
2	...do	.42	...do	No	...do	No. 2194.
3	...do	.42	...do	...do	...do	No. 8972.
4	...do	.42	...do	...do	...do	No. 8862, tang broken.
5	Winchester	.44	...do	...do	...do	Rifle, model 1866.
6	...do	.44	...do	...do	...do	Rifle, model 1866; mainspring broken.
7	...do	.44	...do	Yes	...do	Rifle, model 1866.
8	...do	.44	Round	...do	...do	
9	...do	.44	...do	...do	...do	Carbine.
10	...do	.44	...do	...do	...do	Do.
11	...do	.44	...do	...do	...do	Do.
12	...do	.44	...do	...do	...do	Do.
13	...do	.44	...do	...do	Broken	Carbine; butt-stock broken.
14	...do	.44	...do	...do	...do	Do.
15	...do	.44	...do	...do	New	Carbine.
16	...do	.44	...do	...do	...do	Do.

TABLE IV.

Spencer carbines, model 1865 (using rim-fire metallic cartridges).

No.	Caliber.	Breech system in working order or not.	Condition of stock.	Remarks.
	"			
1	.52	Yes	Worn	
2	.52	...do	...do	
3	.52	...do	...do	
4	.52	...do	...do	
5	.52	...do	Butt-stock and tip-stock cracked	
6	.52	...do	...do	
7	.52	...do	...do	
8	.52	...do	Worn	Side-plate gone.
9	.52	...do	...do	
10	.52	...do	...do	
11	.52	...do	...do	
12	.52	...do	...do	
13	.52	Yes	...do	
14	.52	No	...do	
15	.52	...do	...do	
16	.52	...do	...do	
17	.52	...do	...do	
18	.54	...do	...do	
19	.54	...do	...do	
20	.54	...do	...do	
21	.54	...do	...do	
22	.50	...do	...do	Octagonal barrel.
23	.50	...do	...do	Rifle, buckhorn rear sight.

TABLE V.

Sharp's carbines (using metallic ammunition).

No.	Caliber.	Breech system in working order or not.	Condition of stock.	Remarks.
	"			
1	.52	Yes	Butt-stock broken	
2	.52	No	Worn	Tang broken; new sight put on.
3	.52	....do	Broken tip-stock	
4	.52	Yes	Worn	
5	.52	....do	....do	Side-screw gone.
6	.52	....do	....do	Side-plate and screw gone; front sight put in.
7	.52	....do	....do	Leaf broken.
8	.50			Butt-plate, leaf, and band gone; new front sight.
9	.52	Yes	Worn	Rifle; butt-plate gone.
10	.52	No	No stock	Rifle; lock gone; copper front sight.
11	.54	Yes	Worn	Uses paper cartridges, No. 17,436.
12	.54	No	......do	Do.
13	.54			Carbine; band gone; uses paper cartridges.

TABLE VI.

Miscellaneous carbines and rifles.

No.	Kind of arm.	Caliber.	Breech system in working order or not.	Condition of stock.	Parts missing.	Kind of cartridges.	Remarks.
		"					
1	Warner	.50	No	Worn	Butt-plate		
2	....do	.50	..do	Broken at small			
3	....do	.50	..do	Side broken			
4	Joslyn	.54	..do	Fair	Butt-plate	Metallic	No. 11601, new barrel.
5	....do	.54	Fair	....do		...do	
6	....do	.54	No	....do		...do	
7	Starr	.54	..do	Worn		Paper	
8	....do	.54	..do	No butt-stock		...do	
9	....do	.54	..do			...do	
10	F. Wesson	.42	Yes	Fair		Metallic	No. 7037, octagonal barrel.
11	....do	.42	..do	Broken	Butt-stock	...do	No. 3752.
12	....do	.42	..do	....do	....do	...do	No. 2186, side plate gone.
13	....do	.35	..do	....do	....do	...do	No. 4079, guard broken.
14	Remington	.50	Fair	....do	Butt-plate and tip-stock.	...do	
15	....do	.50	No		Stock, rear sight	...do	Barrel burst; rifle.
16	Gallager	.52	Yes	Fair		Paper	
17	Merrill	.52	No	Worn		...do	
18	Smith	.50	Yes	....do		...do	
19	Ballard	.50	No	....do		Metallic	Rifle; mainspring broke.
20	....do	.42	..do	Broken		...do	No. 14424; mainspring and tip-stock broken.
21	....do	.42	Yes	Badly worn		...do	Rifle cut down.

TABLE VII.

(*Muzzle-loading rifles; octagonal barrels; percussion-locks.*)

No.	Maker.	Caliber.	Lock mechanism, in working order or not.	Stock, condition of.	Parts missing.	Remarks.
		"				
1	H. E. Leman, Lancaster, Pa	.52	Yes	Worn		Buck-horn rear sight.
2	do	.54	do	do		
3	do	.58	No	Used up		
4	do	.52	Yes	do		
5	do	.58	do	Fair		Barrel short.
6	do	.54	do	Broken, small		One notch in tumbler.
7	do	.54	do	Fair		Buck-horn sight.
8	do	.54	No	Broken, small		
9	do	.54	No	do		
10	do	.58	Yes	Broken badly		
11	do	.46	do	do		Short barrel.
12	do	.52	No	Broken		
13	do	.54	Broken	do		Cover off patch-box.
14	do	.54	No	do		Stock held together with rawhide.
15	do	.56	Fair	do		Do.
16	do	.56	Yes	do		One notch in tumbler.
17	do	.54	do	do		Do.
18	do	.54	Fair	do		
19	do	.56	do	do	Butt-plate	
20	do	.50	do	do		
21	do	.56	do	do		
22	do	.54	No	do		
23	do	.54	No	do		
24	do	.54	Fair	Fair		
25	do	.54	do	Broken		
26	do	.56	do	do	Butt-plate	
27	do	.54	No	do		
28	do	.50	Fair	Split		
29	do	.56	No	Broken		
30	do	.56	Fair	do	Butt-plate	
31	do	.54	do	do		
32	do	.44	Worthless	do		
33	do	.50	Fair	Badly worn		
34	do	.54	do	Broken		
35	do	.54	do	Fair		
36	do	.54	Useless	Worn and broken		
37	do	.49	Fair	Worn		
38	do	.54	do	do		
39	do	.54	do	Broken		Improvised guard.
40	do	.54	do	do		

TABLE VII—Continued.

(*Muzzle-loading rifles; octagonal barrels; percussion-locks.*)

No.	Maker.	Caliber.	Lock mechanism, in working order or not.	Stock, condition of.	Parts missing.	Remarks.
		"				
41	H. E. Leman, Lancaster, Pa.	.56	Good	Broken		Flint-lock.
42	do	.54	Fair	do		
43	do	.48	Yes	Worn		
44	do	.50	No	Broken		
45	do	.54	Fair	do		
46	do	.54	No	do		
47	do	.54	Fair	do		
48	do	.56	do	Worn		
49	do	.54	do	Broken	Butt-plate	
50	do	.54	do	do		
51	do	.52	do	do		
52	do	.52	do	do		
53	do	.52	do	do		
54	do	.52	do	Worn		
55	do	.50	No	Worn badly		
56	do	.52	Fair	Broken	Butt-plate	
57	do	.52	do	Worn		
58	do	.52	do	Broken		
59	do	.54	do	do		
60	do	.50	No	Fair		
61	do	.52	Fair	Broken		
62	do	.54	do	Worn		
63	do	.52	do	Broken		
64	do	.50	do	do		
65	do	.52	do	Worn		
66	do	.50	do	Broken		
67	do	.54	do	do	Butt-plate	
68	do	.48	No	do		
69	do	.50	No	do		
70	do	.52	No	Broken and worn		
71	do	.52	No	No stock	Stock	Useless.
72	do	.52	Fair	Broken	Butt-plate	Tip-stock cut off.
73	do	.52	do	Worn and broken		
74	do	.49	do	Worn		Rawhide band.
75	do	.52	do	Broken		
76	do	.52	do	do		
77	do	.51	do	Worn		No ramrod.
78	do	.50	do	Worn and broken		
79	do	.52	do	Worn and badly broken		
80	do	.52	do	Worn badly and broken		
81	do	.38	do	Broken	Ramrod	Rawhide band around small of stock.

82	do	.50	do	Used up		
83	do	.45	do	Worn badly		
84	do	.54	do	Broken		
85	do	.49	do	Fair	Ramrod	Cone broken off.
86	do	.52	do	Broken and worn		
87	do	.52	do	Badly worn	Ramrod	
88	do	.52	do	do		
89	do	.54	do	Broken	Ramrod	
90	do	.52	No	do		Tang broken.
91	do	.54	Fair	do		
92	do	.54	do	Worn and broken	Ramrod	
93	do	.54	Broken	Split and broken		
94	do	.52	do	Badly broken		
95	J. P. Lower, Philadelphia, Pa	.56	Yes	Broken	Patch-box lid	
96	do	.52	Fair	do		
97	do	.52	do	do		Buck-horn sight.
98	do	.52	Poor	do		
99	do	.52	No	do		
100	do	.52	Fair	do	Butt-plate	
101	do	.52	do	Fair		
102	do	.52	do	Worn		
103	do	.52	do	do		
104	do	.52	No	Worn and broken	Lock	No hammer.
105	S. Hawken, Saint Louis, Mo	.58	No	Worn		Buck-horn sight; set trigger broken.
106	do	.54	Fair	Broken		
107	do	.52	do	Worn		Rawhide strap.
108	do	.52	Fair	Broken	Guard-plate	
109	do	.46	do	Worn		Set trigger.
110	do	.52	Yes	Fair	Ramrod	
111	J. Henry & Son	.54	No	Broken		Buck-horn sight and set trigger.
112	do	.56	Good	do		Set trigger; stock tied up with rawhide.
113	do	.56	No	do		Guard loose.
114	do	.50	Good	Worn		Set trigger.
115	do	.50	Fair	Small, broken		
116	do	.52	Broken	Broken		Do.
117	Henry Folsom & Co., Saint Louis, Mo.	.54	Yes	Worn		
118	do	.54	Fair	Fair		
119	do	.52	do	Worn		
120	do	.52		Broken		
121	J. and W. Watson	.44	No	do		Short barrel.
122	Sweitzer	.49	No	Used up		Set trigger.
123	J. Golcher	.56	No	Broken	Butt-plate	
124	do	.52	No	do		
125	do	.52	Fair	do		
126	Springfield	.58		Broken, round barrels		Altered by Savage Fire Arms Company, Middletown, Conn.
127	do	.58	Good	Worn, round barrels		Made by Colt and Co.; short barrel.
128	do	.58	do	do	Butt-plate	Made by Parker, Snow & Co., Middletown, Conn.; buck-horn sight.
129	Springfield	.58	Good	Worn, round barrels	Butt-plate	Altered by E. Whitney.
130	do	.58	Fair	Broken, round barrels	do	Rifle cut down; made at Watertown, N. Y.
131	do	.69	do	do	do	Model 1822, made in 1832; smooth-bore.

TABLE VII—Continued.

(*Muzzle-loading rifles; octagonal barrels; percussion-locks.*)

No.	Maker.	Caliber.	Lock mechanism, in working order or not.	Stock, condition of.	Parts missing.	Remarks.
		"				
132	Springfield	.58	Good	Worn, round barrels	Butt-plate	Model 1864; barrel cut down.
133	do	.69	do	do	do	Model 1822; barrel cut down; smooth-bore.
134	do	.58	Fair	do		Model 1855; made by E. Whitney, New Hampshire.
135	do	.69	do	do	Butt-plate	Made at Harper's Ferry, 1848.
136	do	.54	do	do		Made at Harper's Ferry; rifle cut down.
137	do	.54	Good	Cut-down, round barrels		Made at Harper's Ferry.
138	do	.58	do	Broken, round barrels		Whitneyville, 1863.
139	do	.54	No	Worn, round barrels		E. Whitney, New Hampshire, 1851.
140	Penn Rifle Works	.46	No	Broken	Butt-plate	Short barrel.
141	Savage Rifle Fire-arm Company, Middletown, Conn.	.52	Good	do		Springfield lock.
142	W. Chance & Son, London	.58	No	Fair		Flint-lock; smooth-bore.
143	Parker, Field & Co., 1867	.58	Fair	do		Do.
144	Tower gun, 1861 (English)	.58	do	do		Smooth-bore.
145	do	.58	Yes	Broken		Carbine.
146	do	.58	do	Bad	Butt-plate	Cut down.
147	Tower gun, 1862 (English)	.58	Fair	do	do	Improvised band.
148	McCaran, Williams & Co., Saint Louis, Mo.	.52	do	Broken	Ramrod, leaf	
149	J. H. Schmelzer, Leavenworth, Kans.	.48	Yes	Good	Ramrod	
150	G. D. & Co., Cincinnati, Ohio	.58	No	Badly worn	do	Tang broken.
151	G. Spangler	.50	Broken	Broken		Guard broken.
152	London Arms Co., 1861 (English)	.58	Yes	Worn		
153	Enfield (English)	.58				
154	R. Beauvais, Saint Louis, Mo	.52	Fair	Broken		
155	Merrill, Baltimore	.54	No	Fair		Breech-loader, percussion cap.
156	Gallager	.52	Fair	Broken		Do.
157	Unknown	.50	Yes	Worn		Buck-horn sight and set trigger.
158	do	.52	No	Broken	Butt-plate	Short barrel; name effaced from lock-plate.
159	do	.52	Broken	do		
160	do	.58	Fair	do		
161	do	.58	No	Worn-out		Smooth-bore.
162	do	.52	Fair	Broken		

TABLE VIII.

Revolvers (using percussion caps).

Number.	Kind of arm.	Caliber.	Mechanism in working order or not.	Condition of stock.	Parts missing.	Remarks.
		"				
1	Colt's dragoon	.44	Fair	Worn	Ramrod	
2	Colt's navy	.36	No	....do		
3	....do	.38	Fair	....do		
4	Colt's dragoon	.44	Hard	....do		Parts broken.
5	....do	.44	Fair	....do		
6	....do	.44	Hard	....do		
7	....do	.44	No	....do		Parts broken.
8	....do	.44	....do	Bad		Stock and guard loose.
9	....do	.44	Fair	Worn		
10	....do	.44	....do	....do		
11	....do	.44	....do	....do		
12	....do	.44	....do	....do		
13	....do	.44	....do	....do		
14	....do	.44	Yes	....do		
15	....do	.44	....do	....do		
16	....do	.44	No	....do	Screws	
17	....do	.44	Fair	....do	Ramrod	
18	....do	.44	No	....do	Ramrod and screws.	
19	....do	.44	Fair	....do	....do	Works loosely.
20	Colt's navy	.36	No	....do		Useless.
21	Colt's dragoon	.44	....do	....do		Cylinder loose.
22	....do	.44	....do	....do		
23	....do	.44	Fair	....do		
24	....do	.44	....do	....do	Ramrod	
25	....do	.44	No	Cracked		Ivory handle.
26	....do	.44	....do	Worn	Base-pin	
27	....do	.44	....do	....do	Ramrod and lever.	
28	Colt's navy	.36	Fair	....do		Badly damaged.
29	....do	.36	....do	....do	Frame-screw	
30	Colt's dragoon	.42	No	....do	Lever-catch	
31	....do	.44	....do	....do		
32	....do	.44	Fair	....do		Works loosely.
33	....do	.44	No	....do	Key-pin	
34	....do	.44	....do	....do		
35	....do	.44	Fair	....do	Screws	
36	....do	.44	....do	....do		
37	....do	.44	No	....do		Frame broken.
38	....do	.44	....do	....do		Rusted badly.
39	....do	.44	Fair	....do		Rusty.
40	....do	.44	....do	....do		Loose.
41	Colt's navy	.36	....do	....do		
42	Colt's dragoon	.44	....do	....do		
43	....do	.44	....do	....do		
44	....do	.42	No	....do		Dowel broken.
45	....do	.44	Fair	....do		
46	....do	.44	....do	....do		Tied together.
47	Remington	.44	....do	....do		
48	....do	.44	....do	Broken		
49	....do	.44	Hard	....do	Lever-catch	
50	....do	.36	Fair	....do		
51	....do	.44	No	....do		Spring broken.
52	....do	.44	With difficulty.	....do		
53	....do	.44	Fair	Broken and worn.		
54	....do	.36	No	Worn		
55	....do	.44	....do	....do		
56	....do	.44	Fair	....do		
57	....do	.44	No	....do		
58	....do	.36	....do	....do		
59	....do	.44	Fair	....do		
60	....do	.44	No	....do	Lever-stud	
61	....do	.44	Fair	....do		
62	....do	.44	....do	....do		
63	....do	.44	No	....do		
64	....do	.44	....do	....do		
65	....do	.44	Fair	....do		
66	....do	.44	....do	....do		
67	....do	.44	....do	....do		
68	....do	.44	....do	....do		
69	....do	.44	No	....do		
70	....do	.44	Fair	....do		

TABLE VIII—Continued.

Revolvers (using percussion caps)—Continued.

Number.	Kind of arm.	Caliber.	Mechanism in working order or not.	Condition of stock.	Parts missing.	Remarks.
		"				
71	Remington	.40	No	Broken		
72	....do	.44	....do	Worn	Catch	
73	....do	.44	Fair	....do		
74	....do	.44	No	....do	Catch	
75	....do	.44	....do	....do		
76	....do	.44	....do	....do		
77	....do	.44	....do	....do		
78	....do	.44	Fair	....do		
79	....do	.44	...do	....do		
80	....do	.44	No	....do		Broken.
81	....do	.44	....do	....do		
82	....do	.44	....do	....do		Can be turned by hand.
83	Colt	.37	Fair	....do		
84	....do	.37	....do	....do		
85	....do	.37	No	....do		Mainspring broken.
86	....do	.37	Fair	....do		
87	Colt's army	.45	No		Stock	Metallic cartridges.
88	Colt	.37	....do	Worn		
89	....do	.37	Fair	....do		
90	....do	.37	....do	....do		
91	....do	.37	....do	....do		
92	....do	.37	Hard	....do	Lever-catch.	
93	....do	.37	Fair	....do		
94	....do	.37	....do	....do		
95	....do	.36	....do		Stock	Burned.
96	....do	.37	No	Worn	Lever-catch	
97	....do	.37	Fair	....do		
98	....do	.37	...do	....do		
99	....do	.37	No	....do		Base-pin loose.
100	....do	.37	.. do	....do		
101	....do	.37	...do	....do	Lever-catch.	Mainspring broken.
102	....do	.37	Fair	....do		Nickel-plated; barrel burst at muzzle.
103	....do	.37	No	....do		
104	....do	.44	....do		Stock and frame.	
105	....do	.37	Fair	Worn	Frame-screw	
106	....do	.37	Hard	....do	Lever-catch.	
107	....do	.37	Fair	....do		
108	....do	.44	...do	....do		
109	....do	.44	.. do	... do		
110	Starr Arms Company, N. Y.	.44	... do	....do		
111	....do	.44	....do	....do	Lever-catch.	
112	....do	.44	No	Broken		
113	....do	.44	Fair	Worn		
114	Pettingill	.44	....do	....do		Double-action "self-cocker."
115	Whitney	.37	No	....do	Lever-catch.	
116	....do	.37	...do	....do		
117	....do	.37	Fair	....do		Nickel plated.
118	....do	.37	...do	....do	Lever-catch.	Do.
119	....do	.37	No	... do		
120	Manhattan	.36	Fair	....do		
121	Savage	.36	No	....do		
122	Remington	.44	....do	....do	Cylinder	
123	Unknown	.44	....do	....do		Badly damaged.
124	Remington pistol.	.50	Yes	....do		Single-loader; metallic cartridge; Remington rifle system.
125	Horse-pistol, United States.		....do	Good		Haston & Co., Middletown, Conn.
126	....do		....do	....do		J. N. Johnson, Middletown, Conn.

TABLE IX.

Weights of charges of powder and lead found in muzzle-loading rifles.

Number.	Kind of arm.	Caliber.	Charge. Powder. Kind.	Charge. Powder. Condition.	Charge. Powder. Weight, grains.	Charge. Bullet. Shape.	Charge. Bullet. Disfigured or not.	Charge. Bullet. Weight, grains.	Patch. Kind.	Patch. Thickness.	Remarks.
		"									
1	H. E. Leman, Lancaster, Pa.	.52	Rifle	Dirty	110	Round	Yes	230	Cloth	One	
2	do	.52	do		60	do	Yes	230	do	do	Cotton.
3	do	.49	do		80	do	Yes	165	Buckskin	do	Do.
4	do	.52	Fine rifle		60	do	Yes	210	Cloth	Three	Do.
5	do	.52	do	Dirty	60	do	Yes	200	do	One	Do.
6	do	.51	Rifle	do	40	do	Yes	230	do	Two	Dusty powder.
7	do	.50	do	do	50	do	Yes	200	None		Powder been wet.
8	do	.52	Meal	Dusty	60	Five slugs	Yes	200	Cloth	Two	
9	do	.52	Fine rifle		90	Round	Yes	230	do	One	
10	do	.38	do	Dusty	40	Long slug	Yes	160	do	Two	
11	do	.50	Rifle	Been wet	60	Round	Yes	190	do	One	
12	do	.45	Meal	Dirty	40	do	Yes	160	do	Two	
13	do	.54	Fine rifle	do	80	do	Yes	160	do	One	
14	do	.49	do	do	50	Slug	Yes	160	do	do	Powder been wet; slug cylindrical.
15	do	.52	do	do	50	Round	Yes	140	do	do	
16	do	.52	Meal	do	35	Slug	Yes	260	None		
17	do	.52	do	Dusty	30	Round	No	230	Cloth	One	
18	do	.54	Rifle	Dirty	70	do	Yes	230	do	do	
19	do	.52	do	Fine	50	do	Yes	230	do	do	Thin patch.
20	do	.54	do	Fine, dirty	30	do	Yes	230	do	do	
21	do	.54	Rifle	Dirty	70	do	No	250	do	do	
22	do	.54	do	Dusty	60	do	Yes	235	do	do	
23	S. Hawken, Saint Louis	.52	Rifle	do		Round	Yes	230	Cloth	do	
24	Springfield	.54	do	Dirty		Cylinder	Yes	230	do	do	Harper's Ferry, 1846.
25	do	.54	do		60	Round	Yes	230	Buckskin	do	Harper's Ferry, 1854.
26	do	.58	Meal	Very dirty	30	do	Yes	220	Cloth	Two	Whitneyville, 1863.
27	Tower, 1862	.58	Rifle	Good	70	do	Yes	240	do	One	English gun.
28	London Arms Company, 1861	.58	do	do	90	do	No	160	Woolen	Two	Do.
29	G. Spangler	.50	Meal	Dirty	60	do	Yes	200	Cloth	do	Cotton patches.
30	McCaran, Williams & Co., Saint Louis	.52	Rifle	do	80	do	Yes	230	do	do	Powder been wet.
31	J. F. Schmelzer, Leavenworth, Kans.	.48	do	do	50	Cylinder slug	Yes	230	do	One	
32	J. Henry & Son	.50	do	Dusty	50	Round	Yes	180	Buckskin	do	
33	do	.52	do	do	80	do	Yes	230	Cloth	do	Cotton patch.
34	J. P. Lower, Philadelphia	.52	do	Fine	40	do	No	200	do	do	Do.
35	G. D. & Co., Cincinnati, Ohio	.58	do	Fine, dusty, dirty	60	do	Yes	330	do	Two	
36	Unknown	.52	do	Fair		do	No	200	do	One	

CLASSIFICATION.

The above arms may be placed in two general classes, viz:

I. Breech-loading arms.
II. Muzzle-loading arms.

SUB-CLASSIFICATION.

- I. Breech-loading arms.
  - Single loaders..
    - Using metallic-case cartridges.
      - Springfield carbine, model 1873 .... cal. ".45
      - Springfield carbine, model 1866 (rifles cut down) . cal. ".50
      - Springfield carbine, model 1868 (rifles cut down) . cal. ".50
      - Springfield carbine, model 1870 (rifles cut down) . cal. ".50
      - Springfield Allin (rifles cut down) .... cal. ".58
      - Sharp's carbine .... cal. ".50–".52
      - Joslyn carbine .... cal. ".54
      - F. Wesson .... cal. ".35–".42
      - Warner .... cal. ".50
      - Remington .... cal. ".50
      - Ballard .... cal. ".42–".50
      - Remington pistol .... cal. ".50
    - Using paper-case cartridges.
      - Sharp's carbine .... cal. ".54
      - Starr carbine .... cal. ".54
      - Smith carbine .... cal. ".52
      - Gallager carbine .... cal. ".52
      - Merrill carbine .... cal. ".52
  - Magazine arms.
    - Using metallic-case cartridges.
      - Henry .... cal. ".42
      - Winchester .... cal. ".44
      - Spencer .... cal. ".50–".52–".54
      - Colt's Army revolver .... cal. ".45
    - Using paper-case cartridges. Revolvers.
      - Colt's dragoon .... cal. ".42–".44
      - Colt's navy .... cal. ".36–".38
      - Remington .... cal. ".44
      - Starr Arms Company .... cal. ".44
      - Whitney .... cal. ".37
      - Manhattan .... cal. ".36
      - Savage .... cal. ".36
      - Pettingill .... cal. ".44
- II. Muzzle-loading arms.
  - With flint locks ....
    - Rifles .... H. E. Leman, Lancaster, Pa .... cal. ".56
    - Smooth-bore .
      - W. Chane & Son, London .... cal. ".58
      - Parker, Field & Co .... cal. ".58
  - With percussion locks...
    - Rifles ....
      - H. E. Leman, Lancaster, Pa..cal. ".38–".44–".45–".46–".49–".50–".51–".52–".54–".56–".58
      - J. P. Lower, Philadelphia, Pa .... cal. ".52–".56
      - S. Hawken, Saint Louis, Mo.....cal. ".46–".52–".54–".58
      - J. Henry & Son ....cal. ".50–".52–".54–".56
      - Henry Folsom & Co. .... cal. ".52–".54
      - J. & W. Watson .... cal. ".44
      - Sweitzer .... cal. ".49
      - J. Golcher .... cal. ".52–".56
      - Springfield .... cal. ".54–".58
      - Penn Rifle Works .... cal. ".46
      - Savage Rifle Fire Arms Co., Middletown, Conn . cal. ".52
      - McCaren, Williams & Co., Saint Louis, Mo.... cal. ".52
      - J. Schmelzer, Leavenworth, Kans .... cal. ".48
      - G. D. & Co., Cincinnati, Ohio .... cal. ".58
      - G. Spangler .... cal. ".50
      - London Arms Company .... cal. ".58
      - Enfield .... cal. ".58
      - Tower, 1861 .... cal. ".58
      - R. Beauvais, Saint Louis, Mo .... cal. ".52
      - Unknown .... cal. ".50–".52–".58
    - Smooth-bore .
      - Springfield .... cal. ".69
      - Unknown .... cal. ".58

TABULAR STATEMENT.

Breech-loaders.

Springfield carbines, caliber ".45, model 1873	19
Springfield carbines, caliber ".50–".58, model 1866–'68'–70, and Allin	30
Henry and Winchester	16
Spencer	23
Sharp's	13
Miscellaneous	23
Total	124

Muzzle-loaders.

H. E. Leman, Lancaster, Pa	94
J. P. Lower, Philadelphia, Pa	10
S. Hawken, Saint Louis	6
J. Henry & Son	6
Henry Folsom & Co., Saint Louis	4
J. Golcher	3
Springfield (various models, &c)	14
Tower, English	4
Unknown	6
Miscellaneous	13
Total	160

Revolvers.

Colt's	69
Remington	41
Starr Arms Company	4
Whitney	5
Miscellaneous	4
Total	123

Pistols.

Remington	1
Horse-pistols	2
Total	3

Recapitulation.

Breech-loaders	124
Muzzle-loaders	160
Revolvers	123
Pistols	3
Total	410

LOADED ARMS.

During the examination it was found that 36 of the muzzle-loading rifles were loaded. These arms had the charges of powder and lead carefully withdrawn and weighed separately. The resulting weights are given below:

1.—TWENTY-TWO LEMAN GUNS.

Charges of powder.			Charges of lead.		
Number of charges.	Weight of each charge, grains.	Total weight, grains.	Number of charges.	Weight of each charge, grains.	Total weight, grains.
2	30	60	1	140	140
1	35	35	4	160	640
3	40	120	1	165	165
4	50	200	1	190	190
6	60	360	3	200	600
2	70	140	1	210	210
2	80	160	8	230	1,840
1	90	90	1	235	235
1	110	110	1	250	250
			1	260	260
22		1,275	22		4,530

Average weight of charge of powder = 57.9 grains. Weight of maximum charge of powder=110 grains. Weight of minimum charge of powder= 30 grains.

Average weight of charge of lead =205.9 grains. Weight of maximum charge of lead=260 grains. Weight of minimum charge of lead=140 grains.

2.—ELEVEN MISCELLANEOUS GUNS.

Charges of powder.			Charges of lead.		
Number of charges.	Weight of each charge, grains.	Total weight, grains.	Number of charges.	Weight of each charge, grains.	Total weight grains.
1	30	30	1	160	160
1	40	40	1	180	180
2	50	100	2	200	400
3	60	180	1	220	220
1	70	70	4	230	920
2	80	160	1	240	240
1	90	90	1	330	330
11		670	11		2,450

Average weight of charge of powder =60.9 grains. | Average weight of charge of lead =222.7 grains.
Weight of maximum charge of powder=90 grains. Weight of maximum charge of lead=330 grains.
Weight of minimum charge of powder=30 grains. | Weight of minimum charge of lead=160 grains

AMMUNITION.

(*For breech-loaders.*)

Kind.	Caliber.	Weight of charge.		For what arm adapted.
		Powder, grains.	Lead, grains.	
	"			
Rim fire	.44	28	202	Henry and Winchester, model 1866.
	.44	26	202	
	.44	23	202	
	.44	28.3	200	
Rim fire	.50	48.6	351	Spencer carbine, model 1865.
Center fire	.52	70	450	Sharp's carbine.
Paper case, center fire	.54	.37	456	Do.
Rim fire	.54	45	360	Joslyn carbine.
Do	.40	28	220	F. Wesson.
Center fire	.44	30	220	Ballard.
United States center fire	.50	70	450	Springfield, caliber ".50.
Do	.45	70	405	Springfield, caliber ".45.
United States center fire carbine	.45	55	405	Springfield carbine, caliber ".45.
Winchester center fire	.45	40	200	Winchester repeating rifle, model 187[illegible].

SIGHTS.

The front and rear sights of this lot of arms are various, and the different types have been figured in the accompanying plates.

The drawings are self-explanatory.

REMARKS.

These captured arms would be classed as "unserviceable" at an arsenal, though many of them could be used by so enterprising an enemy as the American Indian.

It will be seen by a glance at the foregoing tables that none of the breech-loaders, except the Springfield and Sharp's, are of the later center-fire models.

The charges are uniformly less than the government rifle cartridge.

ORDNANCE DEPOT, TONGUE RIVER, M. T.,
November 13, 1878.

CHIEF ORDNANCE OFFICER,
Headquarters Department of Dakota, Saint Paul, Minn.:

SIR: I have the honor to recommend, in order to complete and render more effective the investigation begun by the Ordnance Department into the relative merits of the service carbine and hostile Indian arms, that measures be taken to obtain an accurate knowledge of the number, manufacture, model, and caliber of fire-arms in the hands of all the savage tribes of Indians, friendly as well as hostile, such as the Sioux, Cheyennes, Crows, Bannocks, Apaches, Utes, Navajos, Comanches, &c. This information, together with the reports regarding surrendered arms, would put the department in possession of all necessary data concerning the weapons of all tribes liable to take the war-path, and be of the highest value in many ways.

I have no doubt that this information could be readily obtained by department commanders. To this end it would only be necessary that competent officers be selected and ordered in an unostentatious way to inspect the various camps, with careful instructions to avoid alarming and causing concealment of the best arms.

Complete statistics as thus obtained would afford the only really satisfactory settlement of the moot question of the comparative merits of the service and Indian arms, for the reason that nearly every discussion regarding surrendered Indian arms proceeds on the assumption that the best have been catched. That this question should be settled is most desirable, in order that the troops have the advantage of a knowledge of superiority in arms, if such be the case, or better arms if the converse, or, in any event, that the facts be faced, always less to be dreaded than the exaggerations of conjecture.

I conceive that many ideas of the superiority of Indian arms are acquired in action, uncorrected by accurate facts, a time when to the best of men an arm that has whizzed a bullet close to the ear seems an excellent weapon; and I feel convinced, from a considerable knowledge of arms carried by friendly Indians and surrendered by the hostiles, that such investigation would prove conclusively that any tribe fully armed with even the old caliber .50 Springfield carbine would be more formidable than with their present arms. That the Sioux and Cheyennes have had some fine breech-loaders, giving color to the opinion that they are better armed than the cavalry, is undoubtedly true. The principal of these, the Sharp's rifle, with its 120-grain cartridge, has tremendous range and penetration, and drifted into the hands of those Indians in considerable number, either directly or indirectly, through the buffalo hunters (with whom it was a favorite) when their employment was broken up by the diminution of the buffalo and by law. But these and like arms are comparatively few, while a very considerable number of muzzle-loaders greatly reduce the average of Indian armament below that of the troops.

In the knowledge of the kind of arms acquired by Indians a good clue may be found to the source whence their supply of arms and ammunition is derived, and aid in detecting and preventing the illicit traffic known to be carried on by taking special precautions against such.

I further recommend that the collection of statistics on Indian arms be continued, in order that the department may keep thoroughly posted,

and that the inspections and reports of Indian arms above recommended be made annually.

Very respectfully, your obedient servant,

J. W. POPE,
Second Lieutenant Fifth Infantry, A. O. O.

HEADQUARTERS DEPARTMENT OF DAKOTA,
OFFICE CHIEF ORDNANCE OFFICER,
Saint Paul, Minn., February 9, 1879.

To the CHIEF OF ORDNANCE,
Through Chief Ordnance Officer, Military Division of Missouri:

SIR: I have the honor to inform you that I omitted to state, in my report on Indian arms of January 22, the following pertinent circumstance of which I have personal knowledge. In July or August, 1876, a Sioux warrior was killed near Powder River after a very determined resistance.

The arm was found to be a Seventh Cavalry carbine, caliber .45 (taken in the Little Big Horn fight, as I was informed by the officers of the regiment), and which, judging from its elaborate Indian ornamentation, had evidently been considered "very good medicine." In other words, the buck had evidently been very glad indeed to get it.

Very respectfully, your obedient servant,

O. E. MICHAELIS,
Captain of Ordnance, Chief Ordnance Officer.

HEADQUARTERS DEPARTMENT OF DAKOTA,
OFFICE CHIEF ORDNANCE OFFICER,
Saint Paul, Minn., January 22, 1879.

To the ADJUTANT-GENERAL,
Department of Dakota:

SIR: I have the honor to submit, for the consideration of the department commander, the following report, in connection with eight guns received from the District of the Yellowstone, under the following instructions:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, October 10, 1878.

The CHIEF ORDNANCE OFFICER,
Military Division of the Missouri, Chicago, Ill.:

SIR: At various times during the last few years, complaints have been made that the service carbine was inferior in range and accuracy to the arms commonly used by the hostile Indians, and within the last few days the fact has been stated that such an opinion was prevalent in the cavalry troops now operating in the Departments of the Missouri and Platte. The Chief of Ordnance wishes to examine thoroughly into this subject, and to that end requests you to procure a sample of the best arms the Indians are known to use, if possible one that has been used by them, and a small quantity of their ammunition.

If you succeed in getting an arm that you are satisfied can be considered a fair sample of the best in use, of course excluding any of the United States service arms that may be in their possession, taken from our troops or otherwise procured, he desires you to send it to this office for examination and comparison.

Respectfully, your obedient servant,

S. C. LYFORD,
Major of Ordnance.

[First indorsement.]

HEADQUARTERS MILITARY DIVISION OF THE MISSOURI,
OFFICE CHIEF ORDNANCE OFFICER,
Chicago, October 12, 1878.

Respectfully referred to the assistant adjutant-general of the division, with the request that the commanding generals of the Departments of Dakota, the Platte, and the Missouri be instructed to obtain, if possible, and forward to these headquarters, a sample of the best arms (excluding the United States service arms) the Indians are known to use, or one that has been used by them, and a small quantity of their ammunition.

J. W. REILLY,
Captain of Ordnance, Chief Ordnance Officer.

Copy to Colonel Miles, October 17, 1878 (from headquarters Department of Dakota), who will send to the chief ordnance officer at these headquarters all arms captured from the Bannocks, and samples of the ammunition that may be in his possession, which have been captured from Indians, which in his opinion are deemed fair samples of the best in use by the Indians.

Referred to chief ordnance officer, Department of Dakota, December 16, 1878.

CLASSIFICATION OF THESE ARMS.

1. A muzzle-loading squirrel-rifle, octagonal barrel, made in Columbus, Ohio, by Seibert; caliber .44.
2. A Sharp's rifle, percussion lock, short barrel, ante-bellum model.
3. A Sharp's carbine, altered lock; caliber .50.
4. A Joslyn carbine, caliber .50.
5. A Spencer carbine, model of 1861.
6. A Sharp's rifle, government model; caliber 50.
7. A Sharp's rifle, short octagonal barrel; caliber .44.
8. A Sharp's rifle, long octagonal barrel; caliber .44.

Nos. 6, 7, and 8 are the only pieces deserving of further mention.

The Sharp's rifle, caliber .50, was fairly tried in the field in comparison with the Springfield musket, caliber .50, and could not hold its own.

Nos. 7 and 8 are Sharp's rifles of a well-known type, with set triggers, originally furnished with peep-sights, and, judging from the numbers, were manufactured about the same time.

I am of the opinion that the barrel of No. 7, which is lighter than that of No. 8, has been shortened.

The fine sights of these guns, upon which their shooting at long range is supposed to depend, have been removed; very coarse front sights, and old model carbine rear sights, altered to buckhorn, have been substituted in an unworkmanlike manner.

These arms are forwarded by General Miles, as a representative of the armament of Indians, and I presume must be accepted as such, with two limitations—the absence of Springfield arms, excluded under the order, and of Henry (Winchester) rifles, both of which are used whenever they can be obtained.

In connection with his Nez Percés engagement, speaking of it and his adversaries, General Miles says: "They have all the enterprise and cunning of wild Indians, and many of the arts of civilized warfare. They are the best marksmen I have ever met, and understand the use of improved sights and the measurement of distances; they were principally armed with Sharp's, Springfield, and Henry rifles, and used explosive bullets."

The sample Nez Percés Sharp's rifle sent (No. 2) has a set trigger, percussion lock, and peep-sight without scale. It certainly cannot be claimed that this gun is comparable with the present government arm, and it is

an accepted fact that our standard caliber outranges the repeating gun. It follows, therefore, from General Miles' report, that the best gun of the best Indian marksman he ever met, so far as range is concerned, was the Springfield rifle.

During my tour of service in this department I have never met an officer, either in the field or at posts, and of course as an ordnance officer I took especial pains to inform myself, who claimed that the Indians, as a class, had longer-ranging guns than our own troops.

As General Miles states of the Nez Percés, the use of fine sights and the measurement of distances is the result of civilization. The typical Indian is a point-blank marksman. The use of bright muzzle and buckhorn sights proves this. He steals upon his quarry and fires *at* it. Hence they prefer arms with long dangerous spaces, an attribute that overcomes the difficulty attending fine sighting and the accurate estimation of distances.

The scouts at Fort Keogh were armed with Sharp's guns, caliber .50, but for this very reason, as I believe, without knowing it, they asked for the Springfield, caliber .45.

It seems to me that there is a periodicity in the claims and rumors concerning the arms of Indians.

In 1876, after the battle of the Little Bighorn, the newspapers were filled with descriptions of the "pumping" guns of the Indians, and requisitions were made for repeating rifles—arms that certainly could not compete with our caliber .45 Springfield rifle or carbine.

An officer of the Seventh Cavalry has informed me that he saw Indians on the banks of the Little Bighorn "*pump*" shots into our troops, struggling up the opposite bank, at a range of fifty yards.

Concerning the two close fights that have taken place in this department since—the Big Hole and Snake River—I have never heard it claimed that the Indians had longer range guns than our own troops. Now, when there have been no close engagements, a lieutenant-colonel of cavalry writes to a United States Senator: "The Indian tribes on our frontiers have excellent arms, and many of our officers and soldiers believe their range is greater than the arms used by us."

Thoughtful and experienced captains of infantry have recommended that one leaf-sight be abolished and the buckhorn substituted, for the reason that our soldiers as a class were not reliable marksmen beyond point-blank range.

In the hands of good shots our gun has always proved satisfactory. I have seen Capt. D. W. Benham, of the Seventh Infantry, now on the Equipment Board in Washington, hit a tree-stump three times in five shots, standing and firing from the shoulder without muzzle rest, at a distance of 1,000 yards, with caliber .45 Springfield rifle taken at haphazard from his company rack. On the Yellowstone, in 1876, General Terry, at a range of 400 yards, with a similar arm outshot both the Sharp's Creedmoor and Winchester guns. General Crook carried a Springfield caliber .45 rifle in the campaign of 1876, and General Gibbon always uses one, hunting and fighting, with buckhorn sight and set trigger, modifications that may affect the accuracy but not the range of the weapon. Reynolds, the guide, who was killed on the Little Bighorn, the best shot in Dakota, carried a government gun. Captain Ball, of the Second, and Captain Benteen, of the Seventh Cavalry, certainly representative company commanders, have both very recently officially reported that they were satisfied with the standard carbine. The same lieutenant-colonel already referred to, in an official communi-

cation of about the same date as his letter to the Senator, writes as follows of the rifle:

> The rifle, owing to its length and weight, cannot be used by a man mounted. Then, again, its length and weight make it too cumbrous and inconvenient. It cannot be carried attached to a sling-belt slung across the back; it is inaccessible, and causes delay in mounting, dismounting, and getting into action. Again, if slung on the pommel of the saddle, it being badly balanced, would soon give the animals sore withers and backs, besides spreading the column greatly.

So far as this officer's opinion is concerned, the plan of arming cavalry with rifles is effectually disposed of.

Our carbine can safely use our 70-grain cartridge, and no carbine of equal weight could use a heavier charge without great danger and intolerable recoil. Complaints have already been made in regard to the severity of the recoil of our present arms using the standard cartridge. What, then, would be the result were we to increase the charge without augmenting the weight?

The longest-ranging Indian arm I have seen is the octagonal-barreled Sharp's rifle, a piece manifestly too heavy to be used as a military arm. If weight is not objected to, an arm can be made at the National Armory that will outrange any gun yet tried. Our rifle at 1,650 yards, using the service ammunition, will penetrate two inches of pine, and therefore *kill*. Is not this enough for all military purposes? If we attempt to accomplish more than this without increasing the weight of the piece the recoil becomes impracticable. Our arms can now kill an enemy so soon as he becomes distinctly visible to the eye, provided he is *hit*. And it is just in this inability to hit that the true source of all dissatisfaction with our standard arms as military weapons is to be found. Our soldiers as a class are not skillful marksmen.

The disjointed system we call "target practice," so far as my observation goes, does very little good in improving our men. I know of one regiment of cavalry where no so-called "target practice" has taken place for a year past. I do not mean to be understood that this was owing to any neglect; it was probably due to the varied duties the men were called upon to perform. Still, the fact remains that while the companies were in garrison nothing was done to improve individual marksmanship.

Where target practice does occur, men fire at known ranges of 100 and 200 yards. This is really an aiming and firing drill, a relic of the military epoch where heavy line firing at known intervals was the custom.

Our fighting now is extended skirmishing, and men should be taught, what I deem the most important attribute of a military marksman, the just estimation of distances. This, our present practice, founded, I believe, upon the Wimbledon system, does not do.

Wimbledon, or our Creedmoor, produces fine dilettanti shots, men who at extraordinary known ranges, by assuming positions impracticable, from a military standpoint, can make any number of successive bulls-eyes. This, however, is not military practice. Our soldiers should be taught to shoot as Captain Benham does—to estimate correctly the distance of the object, and then to *hit* it by fair firing from the shoulder.

As I have repeatedly recommended, we need a thorough system of target practice. Men should be taught the relative sizes of objects, apt to be seen in the field, at varying distances; the Le Boulengé field and musket-telemeters, and no simpler distance measurer can be desired, should be generally introduced.

If this be done, and the target allowance be honestly expended in target practice, our men will become good shots, and these periodically re-

curring animadversions upon the "shooting" qualities of our arms will cease.

I inclose a communication from Lieut. J. W. Pope, Fifth Infantry, acting ordnance officer in charge of the Tongue River Depot, upon the subject of Indian armament, to which I invite especial attention.

Very respectfully, your obedient servant,

O. E. MICHAELIS,
Captain of Ordnance, Chief Ordnance Officer.

HEADQUARTERS MILITARY DIVISION OF MISSOURI,
OFFICE OF CHIEF ORDNANCE OFFICER,
Chicago, June 26, 1879.

CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

SIR: Replying to your letter to me of October 10, 1878, which is inclosed, I have the honor to state that it was referred by me to the assistant adjutant-general of the division October 12, with request for action, as will be seen by the indorsement on its back. The Lieutenant General forwarded copies of this letter to the department commanders, requesting compliance with its terms. Up to this date I have received the papers which are appended and four rifles. The latter are forwarded to you to-day by express.

The subject covers a broader field than any one officer can possibly investigate, and especially when department, post, and regimental officers are not heartily in accord with its purpose.

There are also as many opinions on the subject as there are officers in the service. It would be presumption on my part, therefore, to offer a solution of the general question of the proper armament for cavalry in Indian warfare.

Coming to the special case of the officer in the Department of Missouri, between certain companies of the Fourth Cavalry and the Northern Cheyennes, which was the immediate cause of your letter, I think the papers appended will show the general character of the armament of this band at the time. From these papers I abstract the following lists:

Surrendered by Cheyennes to Captain Johnson, Third Cavalry, at Chadron Creek, Nebr., October 24, 1878.

One Winchester rifle.
One Sharp's carbine, caliber .50.
One Spencer carbine.
One shot-gun, double-barreled.
Nine muzzle-loading rifles, various patterns.
One Schofield-Smith & Wesson revolver.
One Colt's revolver, old pattern.
One Remington revolver, old pattern.
One horse-pistol, and
Fifteen or twenty sets of bows and arrows.

Surrendered at Camp Robinson to Lieutenant Chase, Third Cavalry.

One Henry rifle.
One Sharp's rifle.
Three muzzle-loading rifles.
One Springfield carbine, and
Two unknown patterns.

Captured from Indians after the outbreak at Camp Robinson, giving indication of long possession by Indians.

Seven Springfield breech-loading rifles, caliber .50.
One Springfield carbine, caliber .45.
Three Sharp's carbines, caliber .50.
One Sharp's rifle (old reliable).
One Colt's revolver, caliber .36.
One Colt's revolver, Navy, old pattern.
One Remington revolver, Army, old pattern.

Surrendered to Lieutenant Clarke, Second Cavalry.

Four Springfield carbines, caliber .45.
Three Springfield rifles, caliber .50.
Four Sharp's rifles, caliber .45.
One Sharp's rifle, caliber .50.
Four Sharp's carbines, caliber .50.
One muzzle-loading rifle (old).
Three Winchester and Henry repeating rifles.
Two Colt's revolvers, caliber .45.
Two Smith & Wesson revolvers, caliber .44.
Five Colt's revolvers, calibers .44 and .31.
One Remington revolver, caliber .44.

Or a total armament, as far as ascertained, of fifty-three rifles, carbines, and muskets of various patterns, seventeen revolvers of various patterns, and fifteen or twenty sets of bows and arrows.

In this number there are:

Ten Springfield rifles, caliber .50.
One Sharp's rifle.
One Sharp's rifle (old reliable).
Four Sharp's rifles, caliber .45.
One Sharp's rifle, caliber .50.

Which with proper charges of powder and lead give a greater range than the Springfield carbine with its own special cartridge. I hardly think it just to the command concerned in this affair to exclude United States service arms in possession of the Indians in determining whether there was proper ground for the prevailing opinion that the Indian arms were superior in range and accuracy to the carbine armament of the command.

The four rifles referred to as sent you to-day by express are—

One Sharp's rifle, long.

One Sharp's rifle, short.

One Henry repeating rifle (surrendered at Camp Robinson).

One Winchester repeating rifle (sent from Fort Keogh by order of General Terry).

And are, I believe, selected specimens of the best arms in the possession of the Indians. As is well known to all acquainted with arms, the Henry and Winchester are vastly inferior in range and accuracy to the Springfield carbine, though these seem to be preferred by the Indians on account of their rapidity of fire to the extent of the contents of the magazines, in this respect offering some advantages in a moment of emergency to a horseman.

* * * * * * *

While adhering to my resolution not to attempt a solution of the proper armament of our cavalry, I think it is patent, and that I should state it more explicitly here, that our Springfield carbine, caliber .45, has a greater effective range and greater accuracy than any carbine made, and much greater than the Winchester and Henry repeating rifles. But the Indians do possess a *rifle* here and there, possibly one in ten of their armament, that exceeds it in range and accuracy at long range. To overcome this advantage the method in use in the Fifth Cavalry, giving to each company five Springfield rifles for selected marksmen, and in the Seventh Cavalry, giving ten rifles per company for the same purpose, seems to answer.

* * * * * * *

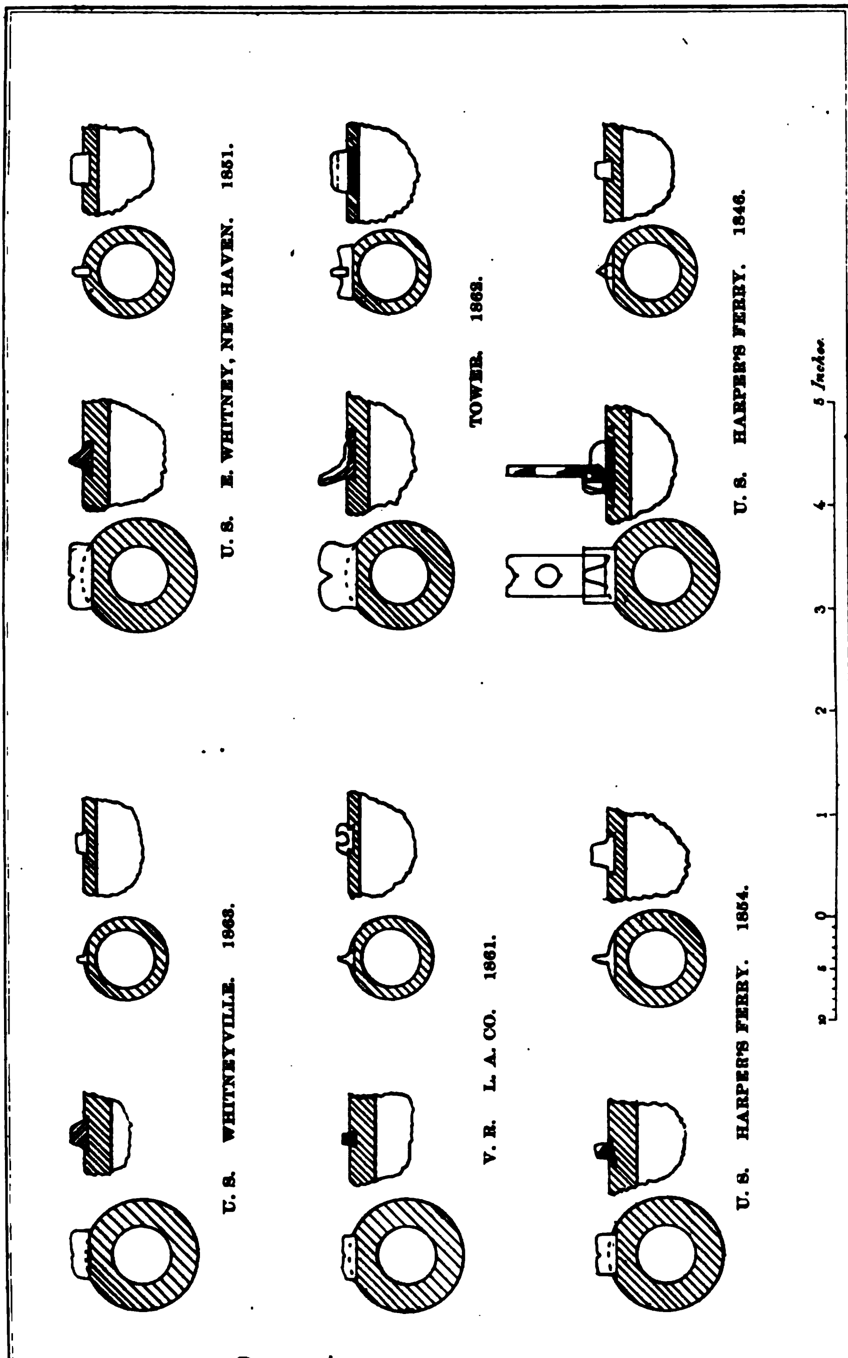
As bearing on the question at issue, it might be stated here that aside from the companies of the Fourth Cavalry serving in the Department of Missouri, which were ordered to be armed with the Springfield rifle, and Companies K and M, Third Cavalry, which had been for some time so armed, none of the companies of cavalry serving in this division have availed themselves of the permission granted by the General of the Army to exchange their carbines for rifles. The only inference from this is that a large majority of cavalry still have faith in the carbine.

Some weeks since I ascertained that 406 surrendered Indian (Sioux and Cheyenne) arms of various patterns had been in the possession of the depot quartermaster at Cheyenne for a year or more. I believe these have been sent, as requested, to the commanding officer of the National Armory, and his special knowledge and the facilities at his disposal will enable him to report upon their merits as compared with the carbine more definitely than I have attempted.

I have delayed forwarding this report in the expectation of receiving the arms before mentioned as captured by Lieutenant Clark, but they have not yet reached me.

Very respectfully, your obedient servant,

J. W. REILLY,
Captain of Ordnance, Chief Ordnance Officer.


U. S. E. WHITNEY, NEW HAVEN. 1851.
TOWER. 1862.
U. S. HARPER'S FERRY. 1846.
U. S. WHITNEYVILLE. 1863.
V. R. L. A. CO. 1861.
U. S. HARPER'S FERRY. 1854.
5 Inches
4
3
2
1
0
5
10

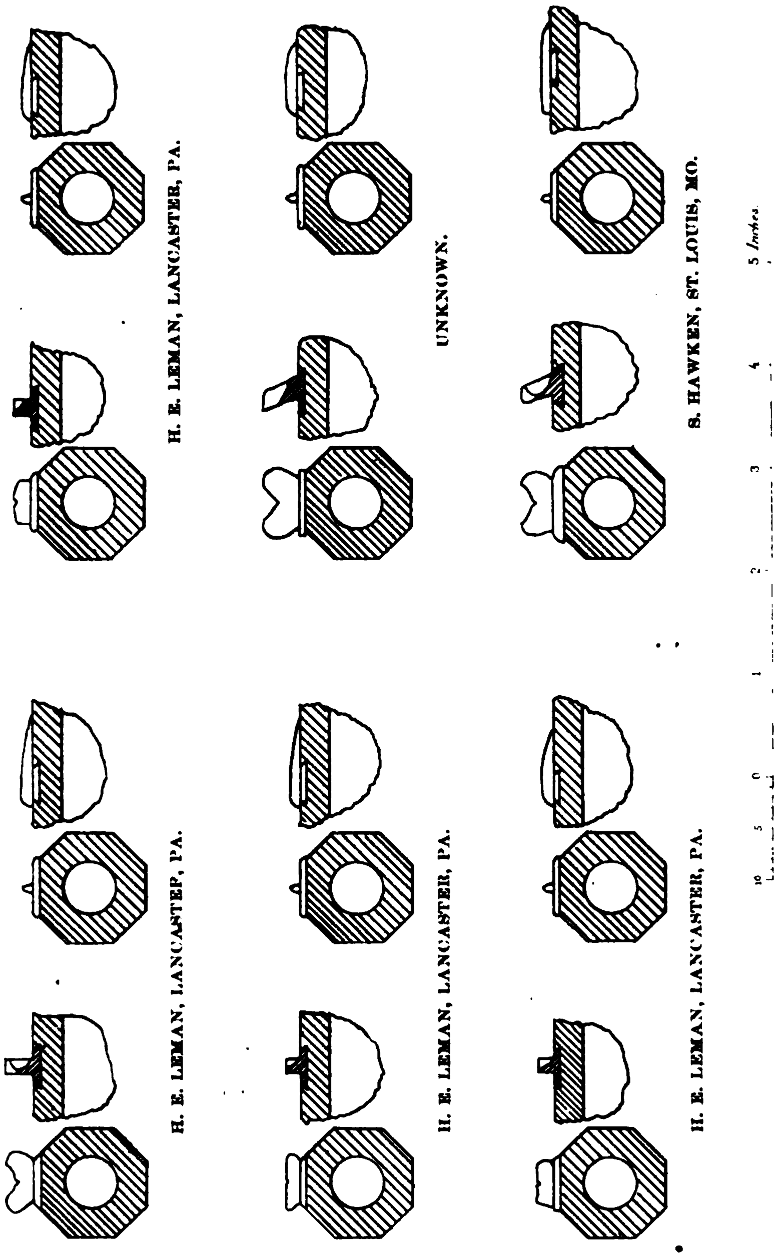
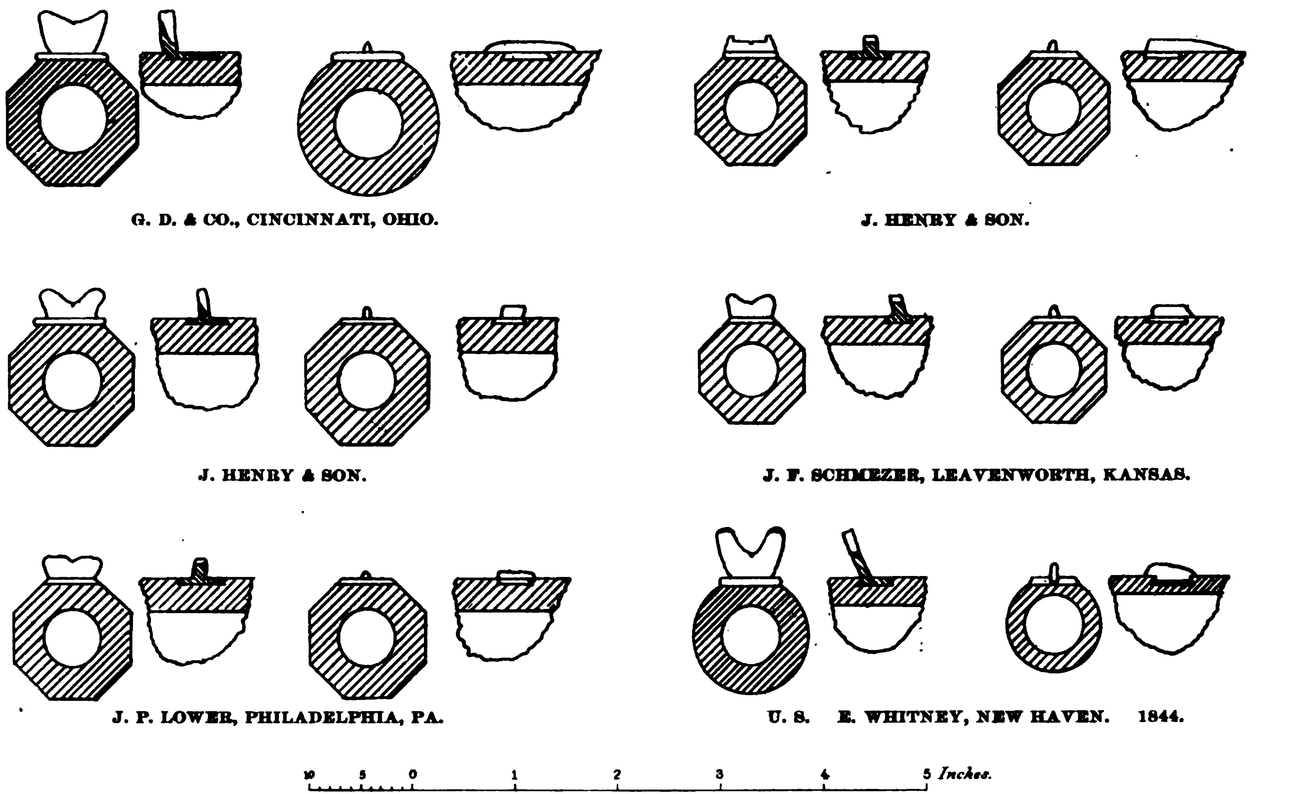
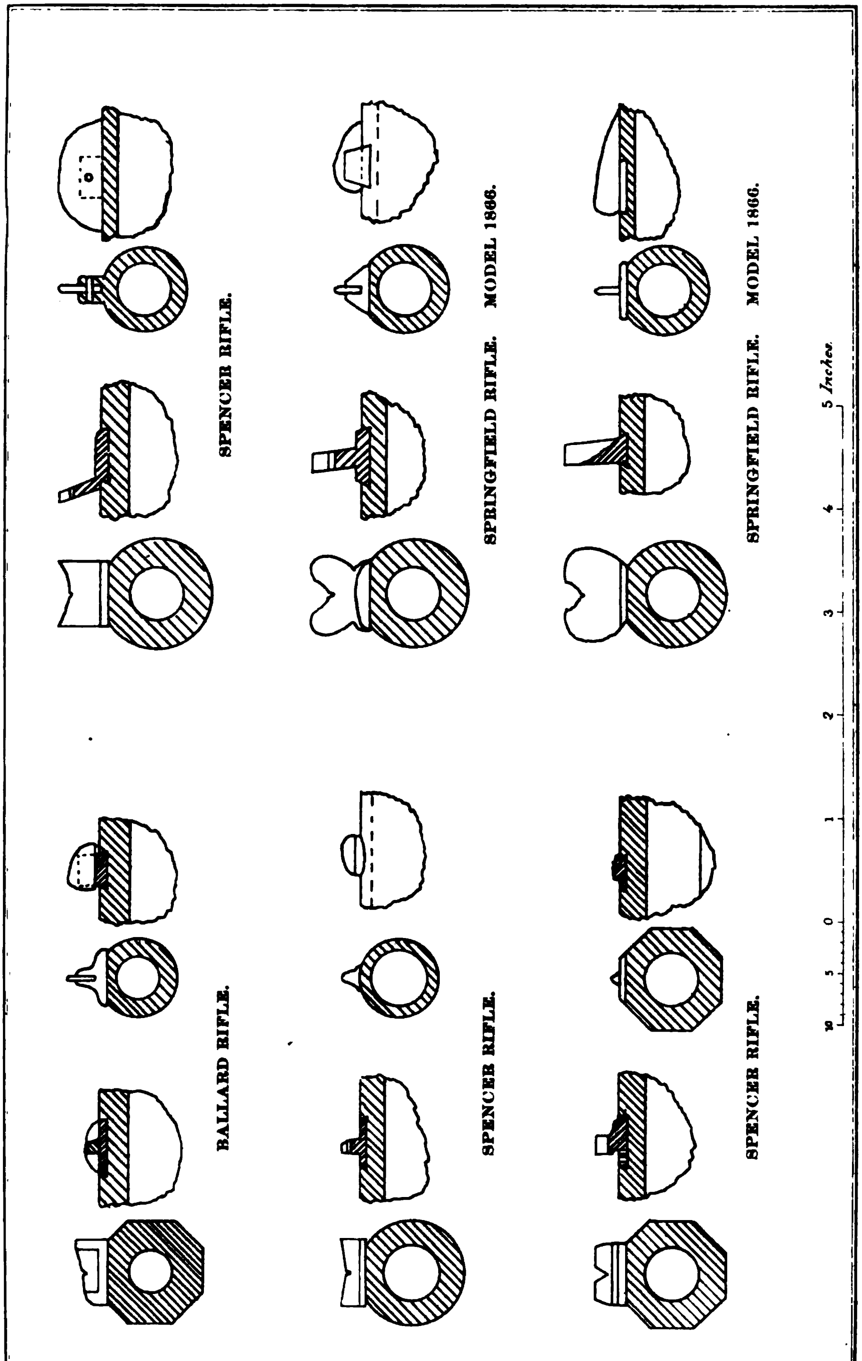
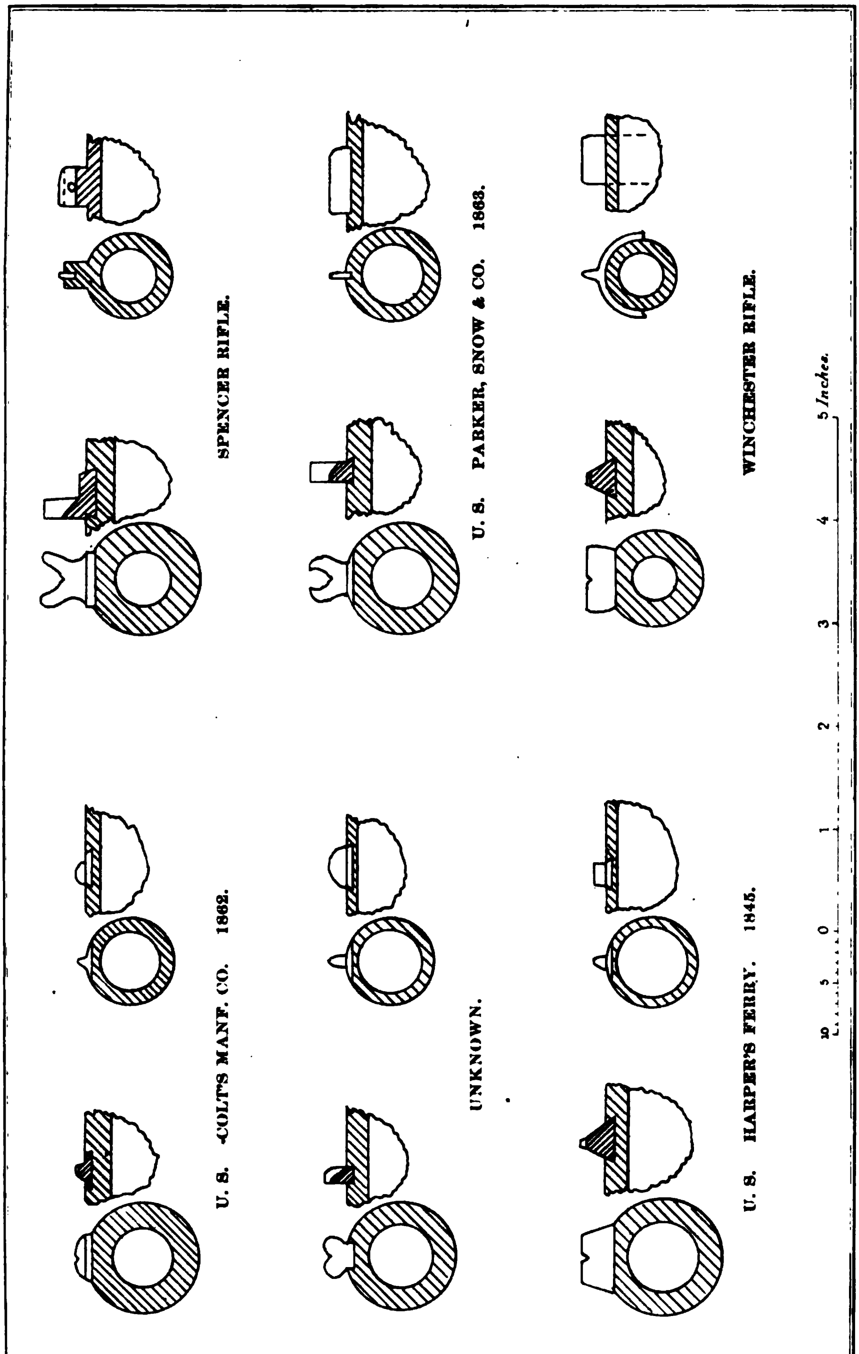

H. E. LEMAN, LANCASTER, PA.
UNKNOWN.
S. HAWKEN, ST. LOUIS, MO.
H. E. LEMAN, LANCASTER, PA.
H. E. LEMAN, LANCASTER, PA.
H. E. LEMAN, LANCASTER, PA.
10 5 0 1 2 3 4 5 Inches.

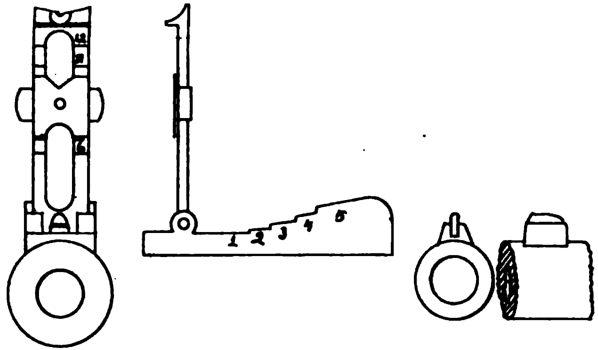
PLATE III.


G. D. & CO., CINCINNATI, OHIO.
J. HENRY & SON.
J. HENRY & SON.
J. F. SCHMEZER, LEAVENWORTH, KANSAS.
J. P. LOWER, PHILADELPHIA, PA.
U. S. E. WHITNEY, NEW HAVEN. 1844.
10 5 0 1 2 3 4 5 Inches.

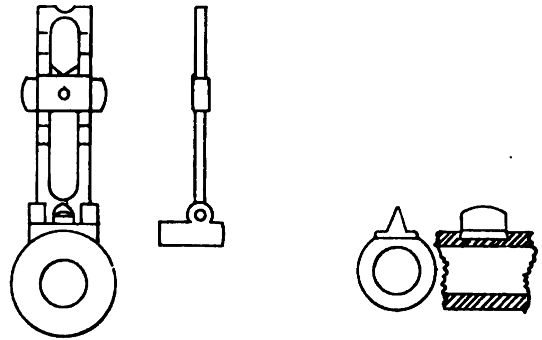

SPENCER RIFLE.
SPRINGFIELD RIFLE. MODEL 1866.
SPRINGFIELD RIFLE. MODEL 1866.
BALLARD RIFLE.
SPENCER RIFLE.
SPENCER RIFLE.
10 5 0 1 2 3 4 5 Inches.



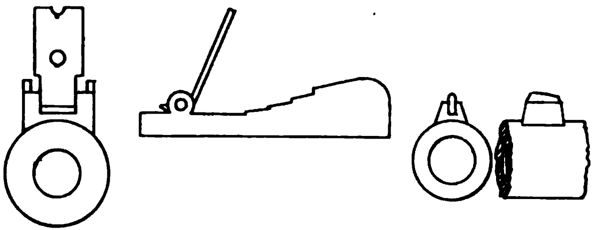
Appendix V.—Report of Chief of Ordnance, 1879.



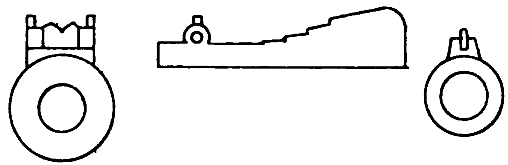
SPRINGFIELD RIFLE, CAL. 0".45.



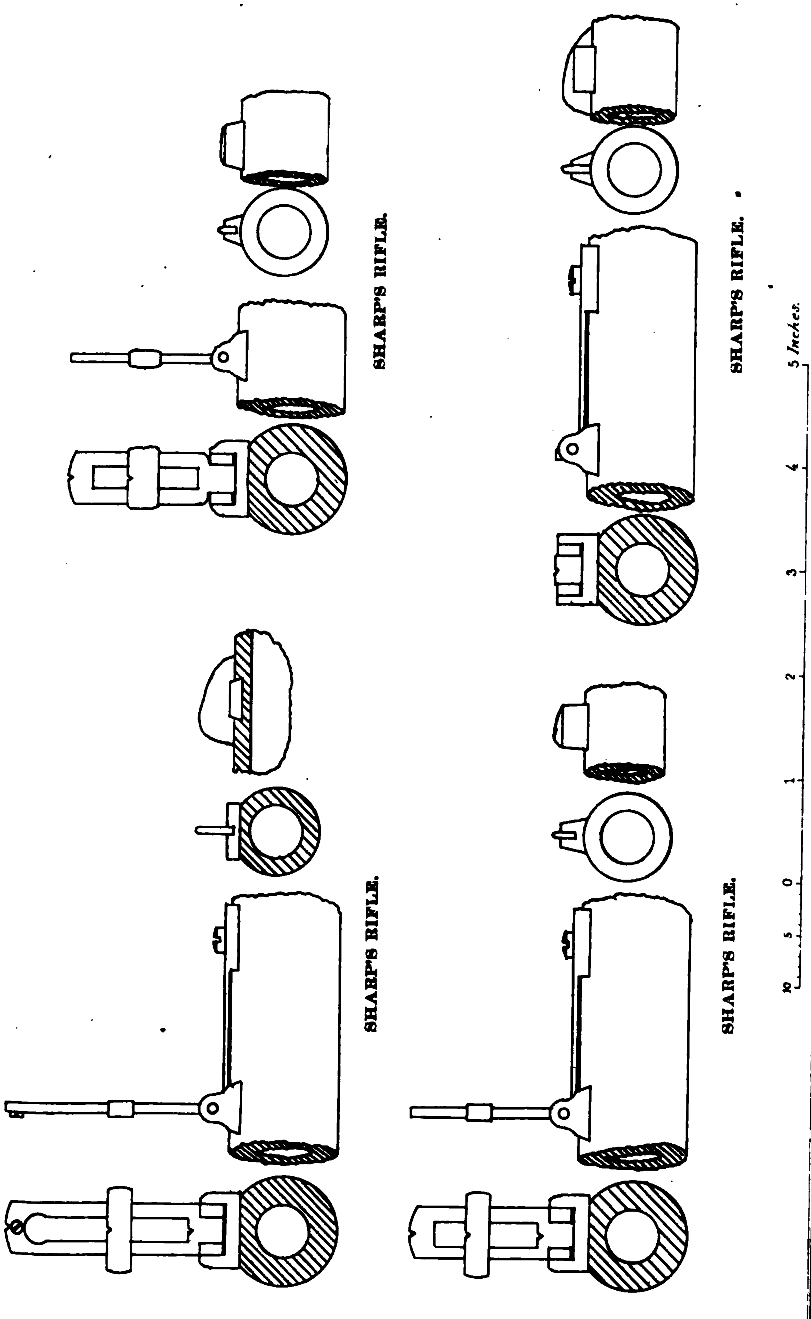
SPRINGFIELD RIFLE, CAL. 0".45.

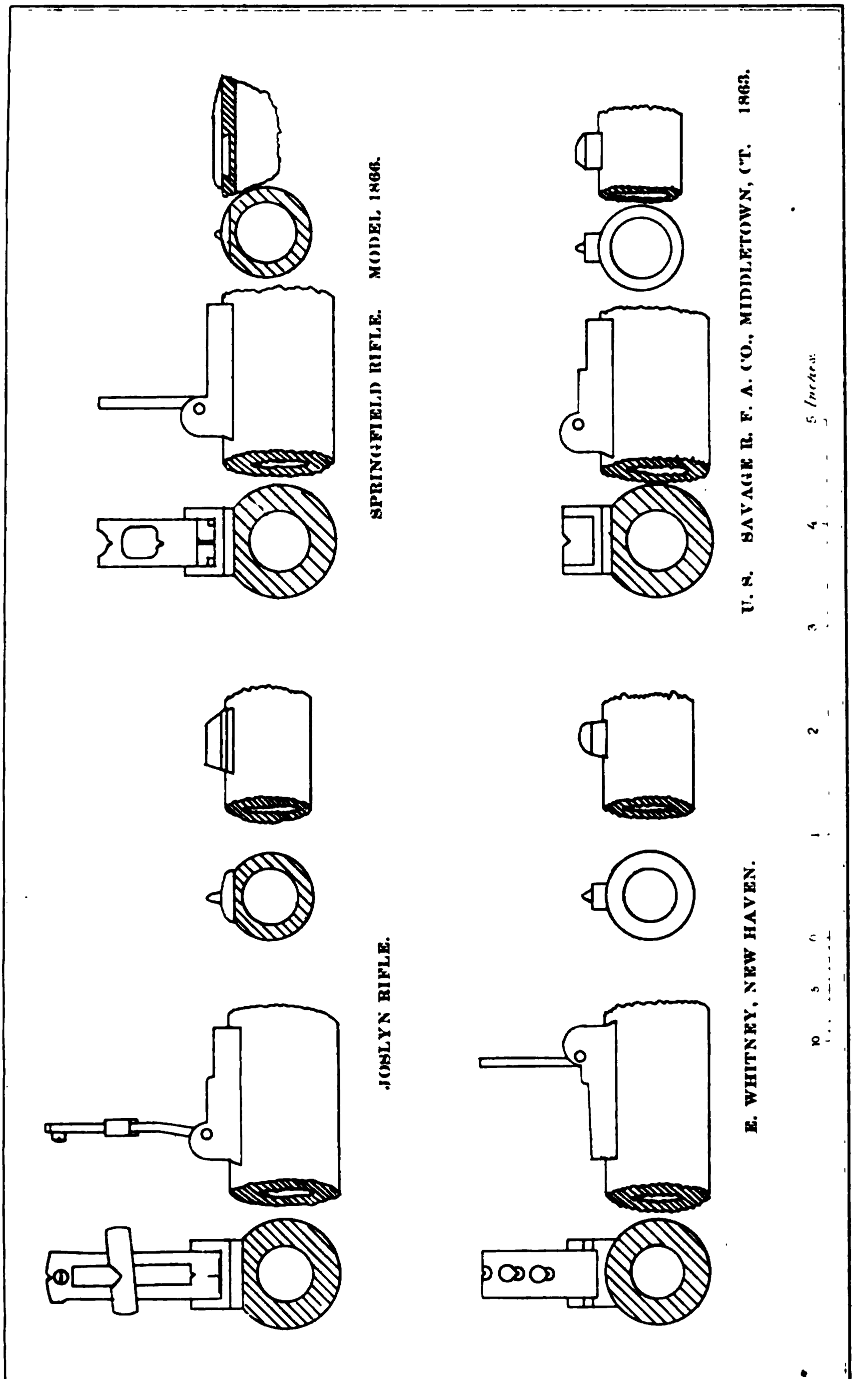


SPRINGFIELD RIFLE, CAL. 0".45.



SPRINGFIELD RIFLE, CAL. 0".45.


SHARP'S RIFLE.
SHARP'S RIFLE.
SHARP'S RIFLE.
SHARP'S RIFLE.
5 Inches.
4
3
2
1
0
5
10



Appendix V.—Report of Chief of Ordnance, 1879.

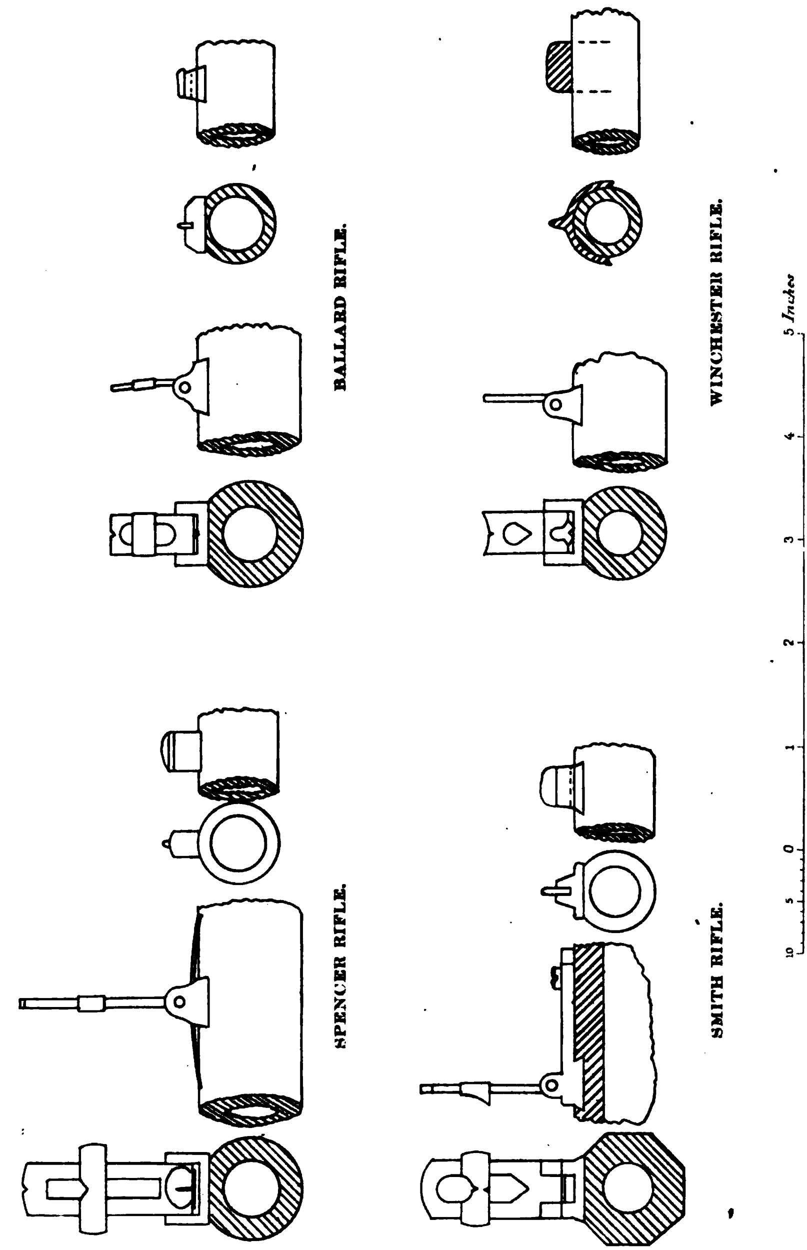
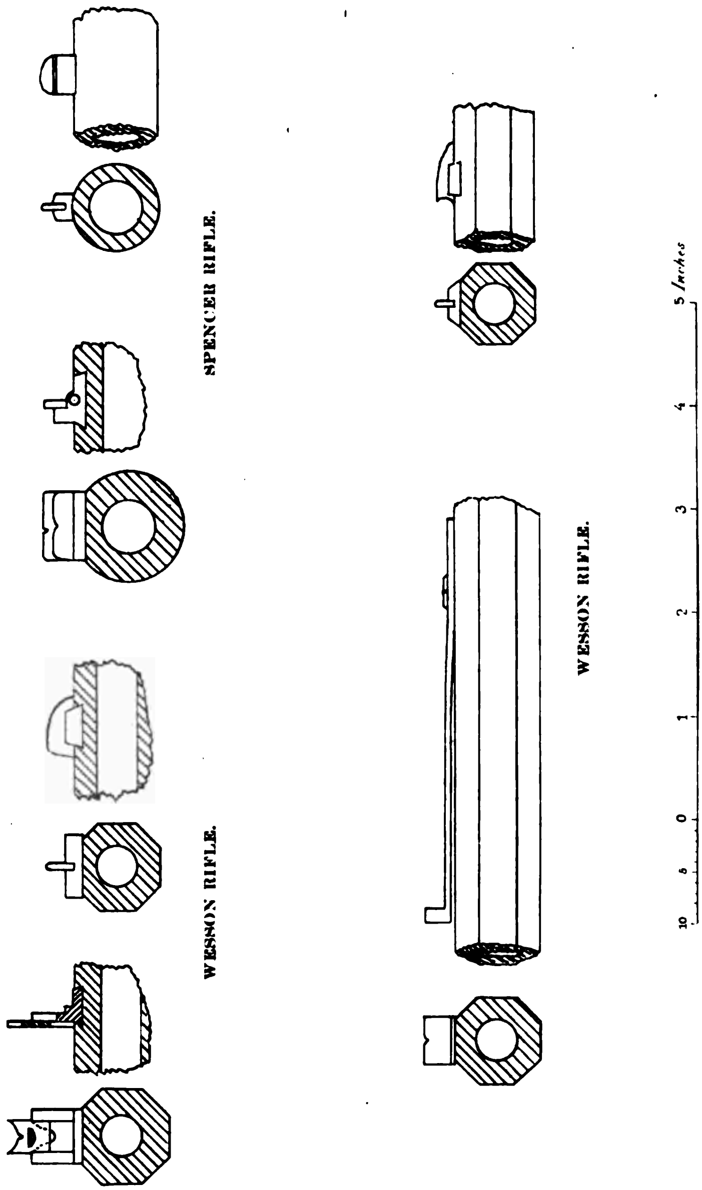

BALLARD RIFLE.
WINCHESTER RIFLE.
SPENCER RIFLE.
SMITH RIFLE.
10 5 0 1 2 3 4 5 Inches

PLATE X.



APPENDIX W.

REPORTS ON MULTIBALL CARTRIDGES FOR SMALL-ARMS.

Maj. J. M. WHITTEMORE, Capts. E. M. WRIGHT and J. E. GREER, and Lieuts. R. BIRNIE, JR., and C. C. MORRISON, Ordnance Department.

(Forty-four plates.)

FRANKFORD ARSENAL, PA.,
June 13, 1878.

The COMMANDING OFFICER,
Frankford Arsenal:

SIR: I have the honor to make the following report:

It has for some time seemed to me that great accuracy and long range in military fire-arms have been sought after by everybody, while too little attention has been paid to destructiveness at short distances. The result of this has been the almost universal demand for the magazine gun.

With a view of increasing the efficiency of our present service arms at comparatively short ranges, I have invented a buckshot or three-ball cartridge, the experiments with which show results sufficiently satisfactory to, at least, be worthy of record.

Any good breech-loader can be fired, with deliberate aim, over five times a minute. In tests for rapidity of fire the Springfield rifle has been fired twenty-three times a minute, loading from the cartridge-box.

Now, any one accustomed to firing knows how deliberate the aim must be to be effective, even at one or two hundred yards. He also knows that it is *the time required to aim, and not so much the time to load, that determines the rapidity of effective fire with the modern breech-loader.*

In the Army and Navy Journal, dated May 25, the following appears:

> Recent official Russian reports show that only 16¼ per cent. of an active army are killed or wounded during a long and exceptionally sanguinary war. The value of the range-finder is shown by the assertion which is made that if the distances had been known a higher result would have been obtained by a single discharge of all the small-arms and guns, using shrapnel for the latter.

We all know that the Turkish army was supplied with excellent arms and ammunition.

When we consider the immense amount of ammunition that will be fired away and wasted, and the difficulty of keeping up the supply in action, it has seemed to me that in seeking the magazine arm as "the gun of the future," without first examining the cartridge, we are only bringing on ourselves "future" trouble without due consideration.

As a fact, a magazine gun is supposed to be used as a single breech-loader, except at *comparatively short range*, and it is its rapidity of fire and great destructiveness, *under such circumstances*, that especially commend it. Now, if we can, by the cartridge, increase two or three fold the destructiveness of our service arms, under *similar circumstances*, do we not to a great extent do away with the requirement for a magazine gun? In fact, all things considered, do we not excel it as the arm for general use? Of course a magazine gun with such a cartridge would be still more destructive, but its construction, cost, delicacy of mechanism, &c., must also be considered.

I do not deny the great results which might be obtained by a special corps armed with the magazine gun, but it seems to me that, for general use, the service arm with a buckshot cartridge, in addition to the present one, is all that would be required. I am aware of the impolicy of increasing the *number* and *kind* of cartridges for small-arms, but whether the increased efficiency obtained will not more than compensate for this "impolicy" must be left to the test of practical experience.

With the field-piece we use several different kinds of projectiles for different purposes and at different ranges. It is only proposed to give the soldier two kinds of cartridges, easily distinguished.

I have, by your permission, made the necessary alterations in a service Colt's revolver so as to adapt it to this cartridge. The same can also be made in the Smith & Wesson.

Should the revolvers be thus altered we would then have *a cartridge which could be used in all small-arms*, which would practically be the only one for the revolver and a special one for the rifle and carbine. The cavalry would then have, as now, only two kinds of cartridges, and should the bayonet be done away with, as proposed by some, the infantry could be supplied with a cartridge which could be used equally well in the revolver or rifle.

An examination of the chamber of the Springfield rifle, caliber .50, showed that the length of the cartridge shell could be increased sufficient to get in three buckshot with fifty grains of service powder. The bullets were made of lead and tin, so as to lighten them.

A large portion of the militia is armed with this rifle. For their purposes, used as they are, in ordinary times, only to quell disturbances or suppress riots, this cartridge would seem to possess special features.

The ultimate range of a rifle-bullet is such that, in street-fighting, friends as well as foes are endangered. The buckshot with shorter range would be more efficient and not so dangerous to friends. A Gatling gun, either .45 or .50 caliber, with this cartridge, would literally prove a "a new broom." In the field, provided with a shield and sufficient oscillation, a Gatling gun properly supported could, with this cartridge, send such a shower of bullets as would practically render its position impregnable.

A thousand men in a rifle-pit, firing ten times a minute at an enemy making a charge, would send at them 30,000 bullets, all effective up to 300 yards. One hundred and fifty yards a minute is a fast run, especially when subjected in that time, man for man, to thirty bullets.

A soldier need only carry a few of these cartridges, and their form is such as to readily distinguish them. Their weight, even if carried in addition to the regular number of rounds, ought to be a soldier's lightest load, when he considers the increased protection they afford him.

The changes required in the Colt's revolver to adapt it to this cartridge are:

1st. New cylinder and frame.
2d. A new hand.
3d. Ejector-rod, tube, and spring.
4th. A new gate.

Using, as I have, the present service case for rifle and carbine cartridges, the width of flange necessitated increasing the size of the cylinder or decreasing the number of the chambers. The latter was done and the revolver completed as a five-shooter. The cylinder, frame, hand, and ejector-rod were made new. The ejector-tube was lengthened

and the old gate used. As finished, its weight compares with the service as follows:

Buckshot, empty	2 lbs. 12½ oz.
Service, empty	2 lbs. 6½ oz.
Difference in weight, empty	6 oz.
Buckshot, loaded	2 lbs. 19¾ oz.
Service, loaded	2 lbs. 13 oz.
Difference in weight, loaded	6¾ oz.

The cost of the alteration is variously estimated at from five to nine dollars when made by the quantity. The alteration of the Smith & Wesson would probably cost more; the cost new of both revolvers would be about the same as those in service.

DESCRIPTION OF BUCKSHOT CARTRIDGE, FOR PRESENT SERVICE ARMS AND ALTERED REVOLVERS.—CAL. .45 BUCKSHOT.

Case, present rifle case, uniformly tapered; charge, 40 or 45 grains service powder; 3 round bullets, pure lead; diameter, ″.458; lubricant, bullets dipped in Japan wax, bullets pushed in far enough to afford a good crimp on last one.

The following is the record:

Fired from carbine; fixed rest; distance, 200 yards; target, 15 feet square.

Charge.	Number of shots.	Number of bullets.	Number of hits.	Remarks.
45 grains	25	60	40	No lubricant.
50 grains	20	60	20	Do.
55 grains	20	60	24	Do.
	60	180	84	

Fouling from 180 shots, 233 grains.

Charge.	Number of shots.	Number of bullets.	Number of hits.	Remarks.
45 grains	20	60	56	Lubricant between front and next bullet.
50 grains	20	60	46	Do.
55 grains	20	60	33	Do.
	60	180	135	

Fouling from 180 shots, 3 grains; very strong breeze across line of fire, from right to left.

Charge.	Number of shots.	Number of bullets.	Number of hits.	Remarks.
40 grains	20	60	37	Lubricant in paper cap on top of powder.
45 grains	20	60	39	Do.
50 grains	20	60	44	Do.
55 grains	20	60	36	Do.
	80	240	156	

Fired from rifle; distance, 200 yards; from shoulder, with rest; target, 15 feet square.

Charge.	Number of shots.	Number of bullets.	Number of hits.	Remarks.
45 grains	33	99	63	Lubricant between bullets.

Fired from rifle; distance, 100 yards; from shoulder, with rest; target, 12 feet square.

Charge.	Number of shots.	Number of bullets.	Number of hits.	Remarks.
45 grains	10	30		Lubricant between bullets.
50 grains	10	30		Do.
55 grains	10	30		Do.
60 grains	10	30		Do.
	40	120	114	

Rapid firing from carbine; distance, 100 yards; target, 12 feet square.

Charge.	Number of shots.	Number of bullets.	Number of hits.	Remarks.
50 grains	17	54	27	Time of firing 1½ minutes.
50 grains	17	(*)	19	Do.
55 grains	17	(†)	15	Do.

* Two round bullets and 1 revolver bullet; total bullets, 54. † Service carbine.

The above were fired by a good marksman and show the necessity for the time required for a proper aim.

To test whether firing the buckshot had injured the rifle, a target was made with it, and it was found that while, before, the rifle had fired nine inches low at 300 yards, it now fired four feet and a half high. A possible explanation of this is that the buckshot (especially those without lubricant) took off the sharp edges of the lands; so that the rifle-bullet would then meet with less resistance. At any rate the trajectory was flattened and the rifle improved.

A new rifle was then taken, and targets at three and five hundred yards obtained as follows:

300 *yards.*

Mean vertical deviation	'.296
Mean horizontal deviation	.378
Mean absolute deviation	.48

500 *yards.*

Mean vertical deviation	'.570
Mean horizontal deviation	.625
Mean absolute deviation	.846

Three hundred buckshot cartridges were then fired from the rifle and targets again taken.

300 *yards.*

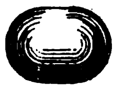
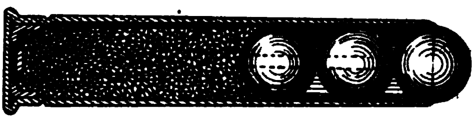
Mean vertical deviation	'.405
Mean horizontal deviation	.247
Mean absolute deviation	.474

500 *yards.*

Mean vertical deviation	'.785
Mean horizontal deviation	.744
Mean absolute deviation	1.081

Showing excellent practice. The targets being taken on different days, would account for the slight difference in mean absolute deviations. No injury to the rifling could be discovered.

I also tried experiments with different shaped bullets. A cylinder of lead and tin just fitting the case was cut of different lengths. Some of these were cut into segments thus:

The results were not satisfactory. I then took a caliber .58 round bullet and drove it through a die one-half inch in diameter, making a bullet of this shape:  Fired the same with caliber .50 bullet for the .45 caliber. In some of these a cannelure was cut for the lubricant thus:  I also bored holes through some of the bullets, and made some cartridges like this,  so that the gas could get to the front bullet, filling the holes with powder; there was no improvement in the results, though driving the bullets through the gun by hand showed they took the rifling, due to their sluggage.

Velocities, recoils, and penetrations of the cal. .45 buckshot cartridge, fired from the rifle; charge, 45 grs.

Velocity: Average of 5 shots	1009.8 feet.
Recoil: Average of 5 shots	77.4 pounds.

Penetration at 200 yards through pine boards $1\frac{1}{8}$ inch thick and over half inch into second board. In some instances through the second board, giving at least one and five-eighth inches penetration.

I send with this report a few bullets picked up in front of the target. They are fair samples.

BUCKSHOT REVOLVER.

(Service Colt altered.)

As soon as the revolver was rough finished I fired it (held in a vise) as follows:

10 shots, 35 grains, 3 bullets.
10 shots, 40 grains, 3 bullets.
10 shots, 45 grains, 3 bullets.
5 shots, 55 grains, 1 service rifle bullet.

Having stood these tests it was then finished, and is a very creditable piece of work to Mr. Dungan, the workman who made it.

The need of a fixed rest was greatly felt, and I had to improvise one. It has worked well and will be the subject of a future report. I have

been able to get velocities, recoils, penetrations, and have measured the tendency of the muzzle to rise or "kick up."

The targets and results follow those obtained with rifle and carbine. As is to be expected, the recoil is more than with the service ammunition. It is, however, not enough to trouble one in firing, while the efficiency of the revolver is increased nearly three times.

REVOLVERS, RECOILS, AND PENETRATIONS.

No tension on recoil spring; target of pine boards ⅞ inch thick, separated by spaces ⅞ inch, distant 25 yards.

Service revolver and service ammunition.

Shot.	Recoil.	Penetration.
	Pounds.	*Inches.*
1	21	7.37
2	20	7.62
3	21	7.75
4	21	7.75
5	21	7.50
6	20	7.50
7	24	7.62
8	20	7.25
9	20	6.25
10	24	7.50
Average	21.2	7.4111

Actual penetration in boards, 3.91 inches.

Service Colt's revolver and Colt's cartridge (30 grains).

Shot.	Recoil.	Remarks.
	Pounds.	
1	22	Penetration through 5 boards ⅞ inch thick, separated by spaces of ⅞ inch. In actual boards 4.37 inches.
2	23	
3	22	
4	22	
5	22	
6	24	
7	25	
8	23	
9	24	
10	24	
11	23	
Average	23.1	

Buckshot; 40-grain charges.

Number of shot.	Recoils.	Penetration at 25 yards.			Average.
	Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	31	4	5.37	5.37	4.91
2	32	4.5	3.5	3.5	3.83
3	33	5.37	4.5	4	4.62
4	30	4	4.5	4.5	4.33
5	30	4.37	5.25	5	5.08
6	32	5.25	5.25	5.25	5.25
7	32	4.5	4.5	7.5	5.50
8	31	5.25	5.5	5.5	5.41
9	32	4.25	4.25	5	4.5
10	32	4	5	4.5	4.5
Average	31.5				4.693

Actual penetration in boards, 2.625 inches.

Buckshot; 45-grain charges; no tension on recoil spring.

Number of shot.	Recoils.	Penetration at 25 yards.			Average.
	Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	33	5.5	5.75	5.5	5.58
2	32	4.75	4.25	4.62	4.54
3	36	5.87	4.5	5.5	5.12
4	34	4.12	5	5	4.70
5	34	4.62	4.25	5	4.62
6	34	6.25	7	5.25	6.16
7	34	6	5	6	5.83
8	36	6	6	5.87	5.95
9	34	5.5	5	5.87	5.45
10	36	5.87	5.25	5.5	5.54
Average	34.3				5.349

Actual penetration in boards, 2.724 inches.

RECOILS.

Spring with initial tension of twenty pounds.

Service.	Buckshot, 40 grains charge.	Buckshot, 45 grains charge.
31	46	49
31	46	48
32	47	49
32	46	47
29	47	47
Average, 31	46.66	48
Greatest variation 3 pounds.	1 pound.	2 pounds.

PENETRATIONS AT 100 YARDS.

Service, 10 shots.

5 through 4 boards ⅞ inch.
5 through 3 boards ⅞ inch.

40-grain buckshot.

8 through 2 boards ⅞ inch.
2 nearly through second board.

45-grain buckshot.

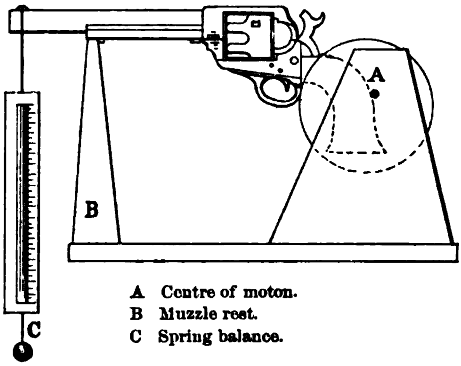
All clear through two boards ⅞ inch and ¼ inch in third board.

VELOCITIES.

Average of five shots.

	Feet.
Service	732
Colt's 30-grain charge	796
Buckshot 35-grain charge	657
Buckshot 40-grain charge	695
Buckshot 45-grain charge	741

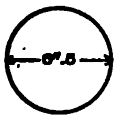
Tendency of muzzle to rise.



A Centre of moton.
B Muzzle rest.
C Spring balance.

Ten pounds initial tension on spring, fastened at front sight. Center of motion. (See figure.)

Service revolver and ammunition.



	Pounds.
Average of 10 shots	19.8
Highest	20
Lowest	19

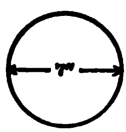
Diameter of circle containing all shots; distance 25 yards, 6½ inches.

Colt's revolver—30-grain charge.

	Pounds.
Average of 10 shots	18.9
Highest	20
Lowest	18

Diameter of circle containing all shots; distance 25 yards, 4¾ inches.

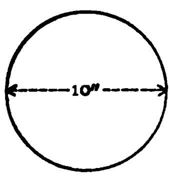
Service ammunition and buckshot revolver.



	Pounds.
Average of 10 shots	18.3
Highest	19
Lowest	17

Diameter of circle containing all shots, 7 inches; distance 25 yards.

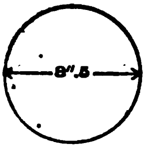
Buckshot cartridge—40-grain charge.



	Pounds.
Average of 10 shots	26.9
Highest	29
Lowest	25

Diameter of circle containing all shots, 10 inches; distance 25 yards.

Buckshot cartridge—45-grain charge.

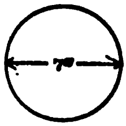


	Pounds.
Average of 10 shots	30
Highest	31
Lowest	29

Diameter of circle containing all shots, 8½ inches; distance 25 yards.

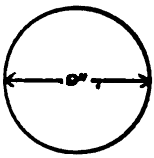
Tendency of muzzle to rise.

Spring with tension of 15 pounds.



Service.—Twenty-four pounds, no variation; diameter of circle containing all shots, distance 25 yards, 7 inches.

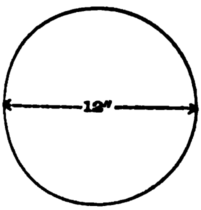
Service ammunition—buckshot revolver.



	Pounds.
Average of 10 shots	19.6
Highest	20
Lowest	19

Diameter of circle containing all shots, distance 25 yards, 9 inches.

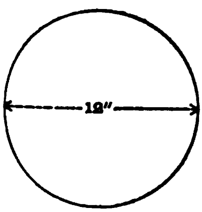
Buckshot cartridge—40-grain charge.



	Pounds.
Average of 10 shots	30.1
Highest	31
Lowest	30

Diameter of circle containing all shots, distance 25 yards, 12 inches.

Buckshot cartridge—45-grain charge.



	Pounds.
Average of 10 shots	32.2
Highest	33
Lowest	32

Diameter of circle containing all shots, distance 25 yards, 12 inches.

The experiments concluded, the revolver was again blued, and, with some cartridges of 40 and 45 grain charges, accompanies this report. The revolver has been fired over 575 times, mostly from the fixed rest, but many times from the hand, with charges varying from 35 to 45 grains. It has been fired over one hundred times without cleaning, and worked well. At 200 yards, the target, 15 feet square, has been hit, firing from the hand, ten times out of five shots; this has been done repeatedly.

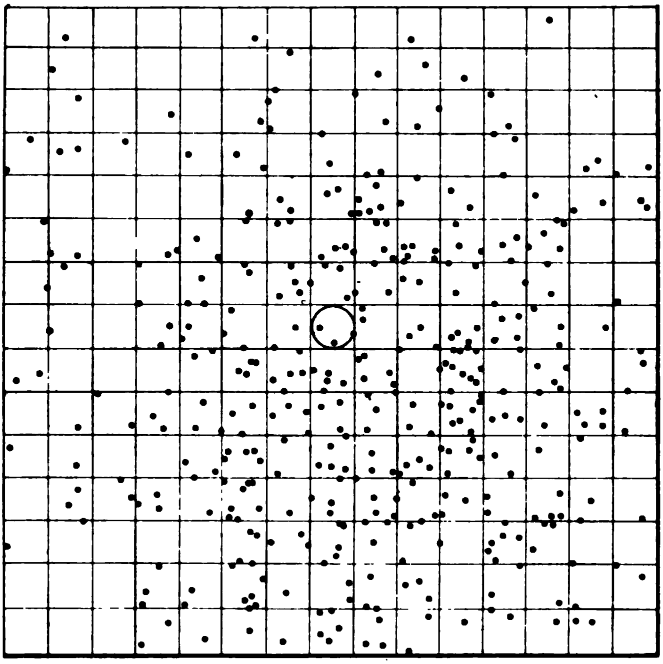
Mr. Porter, foreman of the loading-room at this arsenal, has been indefatigable in his efforts to make this cartridge a success, and I am much indebted to him for many valuable suggestions.

Very respectfully, your obedient servant,

E. M. WRIGHT,
Captain of Ordnance.

TARGET NO. 1.

15 feet square. Distance 200 yards.
200 Buckshot Cartridges.
600 Bullets.
407 Hits.
Stiff breeze from Left to Right, across Line of Fire.



FIRING RECORD.

From Carbine.			From Rifle.		
No. of Shots.	Charge.	Hits.	No. of Shots.	Charge.	Hits.
25	45 grs.	61	25	45 grs.	64
25	50 "	47	25	50 "	50
25	55 "	44	25	55 "	44
25	60 "	50	25	60 "	47
100		202	100		205

The lubricant in these cartridges, which were loaded by hand, was in the interstices between the bullets. The bullets were of pure lead and were those made for the Gatling canister, cal. 1 inch.

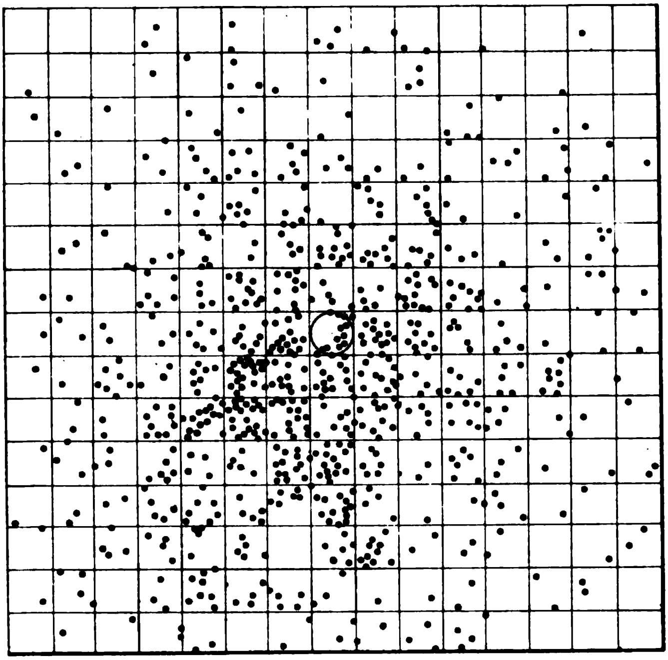
This target shows the superiority of the forty five grain charge at 200 yards, as follows:

Charge 45 grains	50 Shots	125 Hits.
" 50	" 50	" 97 "
" 55	" 50	" 99 "
" 60	" 50	" 110 "

It was the success with this low charge that suggested to me the practicability of using the same cartridge in the revolver.

TARGET NO. 2.

Fifteen feet square. Distance 200 yards.
Three hundred and twenty Buckshot Cartridges.
Nine hundred and sixty Bullets.
Seven hundred and sixty-two Hits.
To determine best Charge, Bullet and method of lubricating. Cartridges loaded on Loading Machine.



FIRING RECORD. *(All from Rifle with fixed rest.)*

No. 1,	Charge 45 grs.	Lead bullets, lubricant bet. last two.		40 Shots.	101 Hits.
" 2,	" 45	" Lead (16) Tin (1)	" " " "	40 "	111 "
" 3,	" 50	" "	" " " "	40 "	101 "
" 4,	" 50	" Lead	" " " "	40 "	99 "
" 5,	" 45	" Lead bullets dipped		40 "	109 "
" 6,	" 45	" Lead & tin	"	40 "	87 "
" 7,	" 50	" "	" "	40 "	76 "
" 8,	" 50	" Lead bullets	"	40 "	78 "
				320	762

The fouling of each 40 shots was as follows:

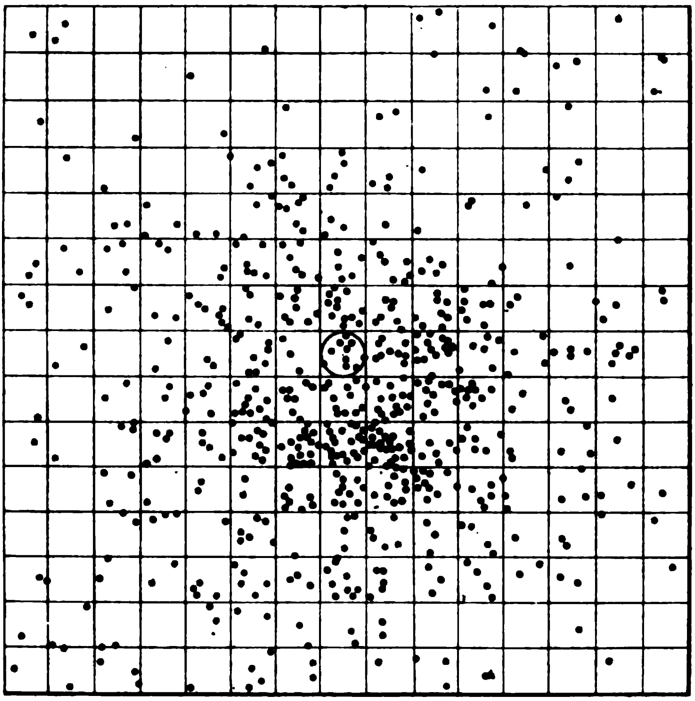
No. 1,	10 grains.	No. 5,	8 grains.
" 2,	12 "	" 6,	11 "
" 3,	11 "	" 7,	5 "
" 4,	11 "	" 8,	3 "

No 5 Ammunition, that is, charge of forty five (45) grains and lead bullet dipped, was selected, all things considered, as the best.

It was found that when the lubricant was between the bullets it would stick to them, retarding their flight, and causing inaccuracy. Many pieces of the lubricant were found on and near the target.

TARGET NO. 3.

Fifteen feet square. Distance, 200 yards.
Three hundred Buckshot Cartridges.
Charge 45 grains.
Three lead Bullets. Weight of each, 133 grains.
Six hundred and twenty-four Hits.
Bullets dipped in Japan wax.



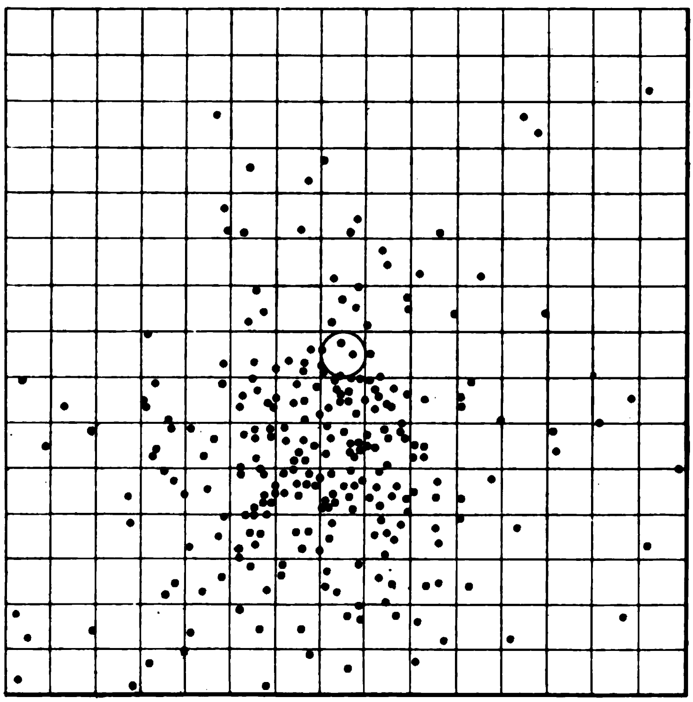
FIRING RECORD.

All fired from Rifle with fixed rest.
Distance 200 yards.
Three hundred Shots.
Nine hundred Bullets.
Six hundred and twenty-four Hits.

Fouling from 1st 100 shots - - - - -	*7 grains*
" " *2d* " " - - - - -	*8* "
" " *3d* " " - - - - -	*6* "

TARGET NO. 4.

Fifteen feet square. Distance 200 yards.
Springfield Rifle, Cal. .45.
Buckshot cartridge, 40 grains.
One hundred shots. Two hundred and fifty-eight Hits.
Fouling, 7 grains.



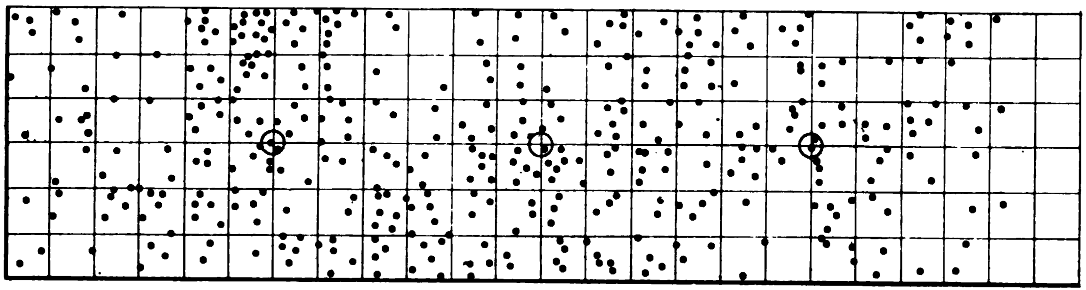
TARGET NO. 5.

6×24 feet.

Ten Ordnance Soldiers firing by file.

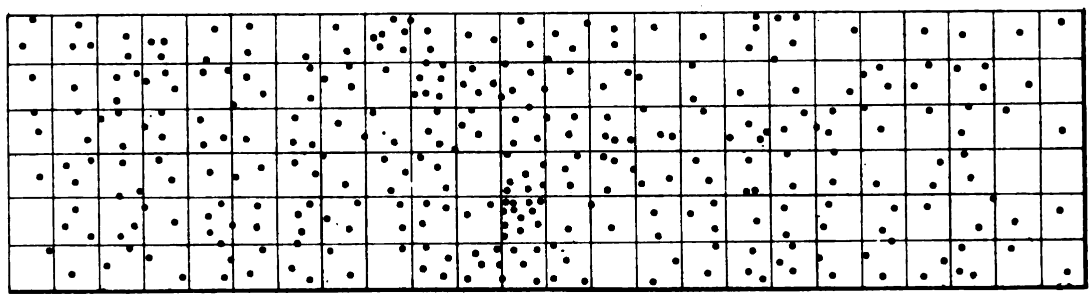
Distance, 215 yards.	*100 Shots, 82 Hits.*		
"	*165 "*	*100 "*	*161 "*
"	*115 "*	*100 "*	*174 "*
Total.	*- -*	*300 shots.*	*417 hits.*

In order to render the trial as unfavorable as possible for the Cartridge, the men were advanced from one range to the other at a double quick.



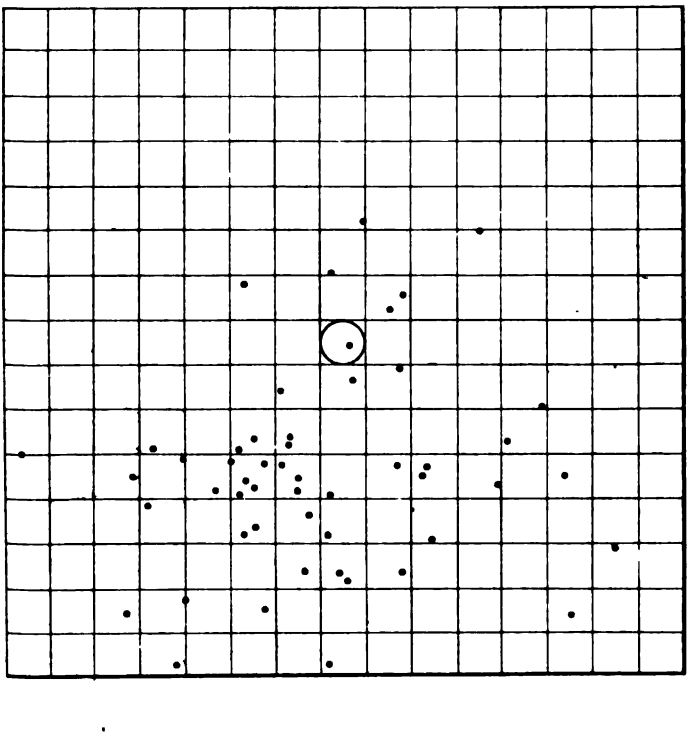
TARGET NO. 6.

Size 6 × 24 feet.
Firing done by ten Ordnance Soldiers by Volley at Command.
Time of firing, 5 rounds per minute.
Buckshot Cartridge—45 grains charge.
300 Shots—328 Hits.
(100 Shots at 215 yards; 100 at 165 yards; and 100 at 115 yards.)



TARGET NO. 7.

Distance, 200 yards.
Caliber .50 Rifle.
20 Shots. 52 Hits.
Buckshot Cartridge.
Charge, 50 grains Service Powder.
3 Bullets. Weight of each, 176 grains.
Target, 15 feet square.
Bullets of lead, 16: Tin, 1.
Have also tried Bullets of lead 10 parts; Tin, 1 part.



TARGET NO. 8.

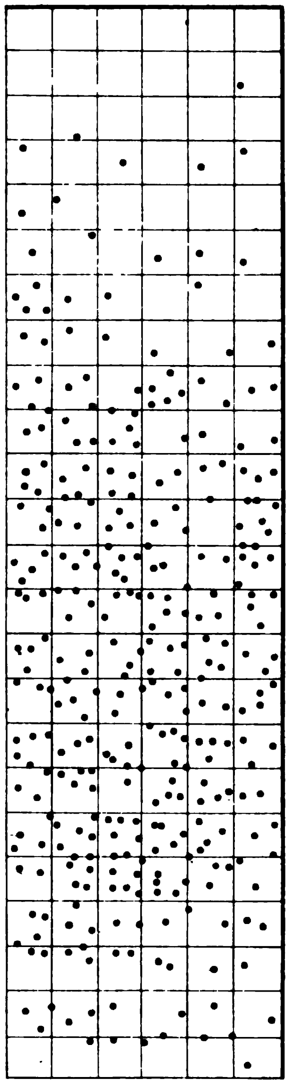
6×24 feet.

Distance, 215 yards.

Fired from Gatling Gun, caliber .45.

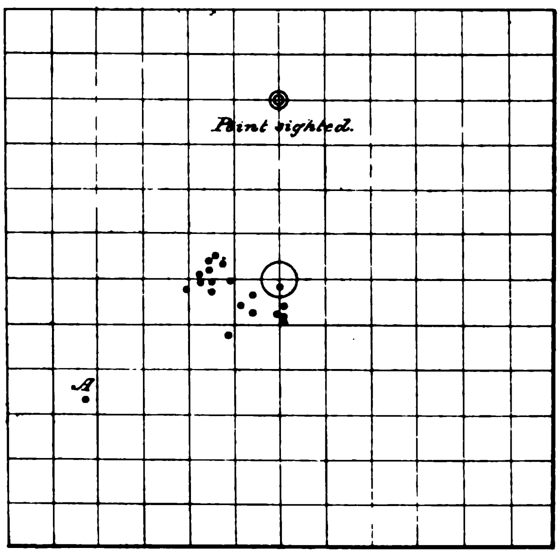
300 Shots. 326 Hits.

Buckshot cartridges, 45 grain Charge.



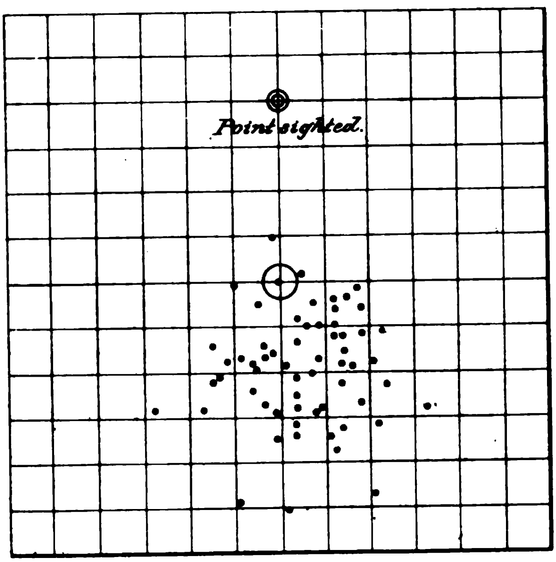
TARGET NO. 9.

Distance, 100 yards.
Twelve feet square.
Service Colt's Revolver.
Service ammunition.
Fired from fixed rest.
Point sighted 4 feet above centre.
Twenty shots. Twenty hits.
Shot marked "A" on Target was from a defective charge, or the Bullet tumbled. Target looked as if the Bullet had struck "side on."



TARGET NO. 10.

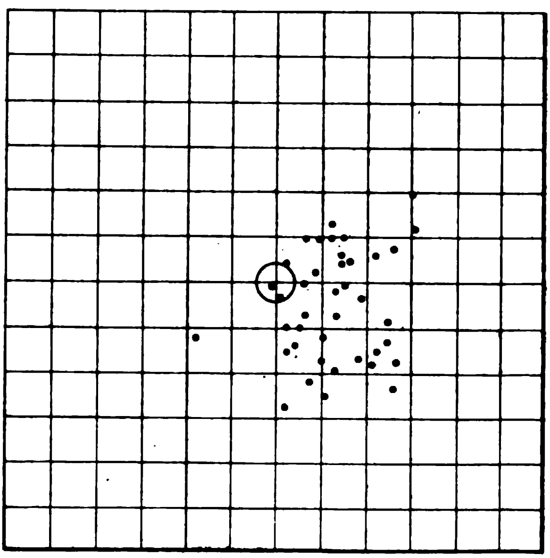
12 feet square.
Distance, 100 yards.
Buckshot Revolver.
Buckshot Cartridges. Charge, 40 grains.
3 Bullets. Weight of each, 133 grains.
Fired from fixed Rest.
Point sighted 4 feet above Center.
20 Shots. 60 Bullets. 60 Hits.



TARGET NO. 12.

12 feet square.
Distance, 150 yards.
Service Revolver---Colt's.
Service Ammunition.
Fired from fixed Rest.
Point sighted two feet above top and centre of Target.
40 Shots. 40 Hits.

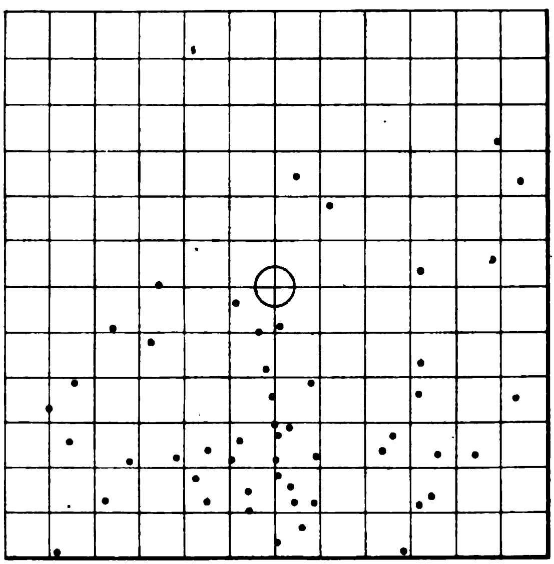
Point sighted.



TARGET NO. 13.

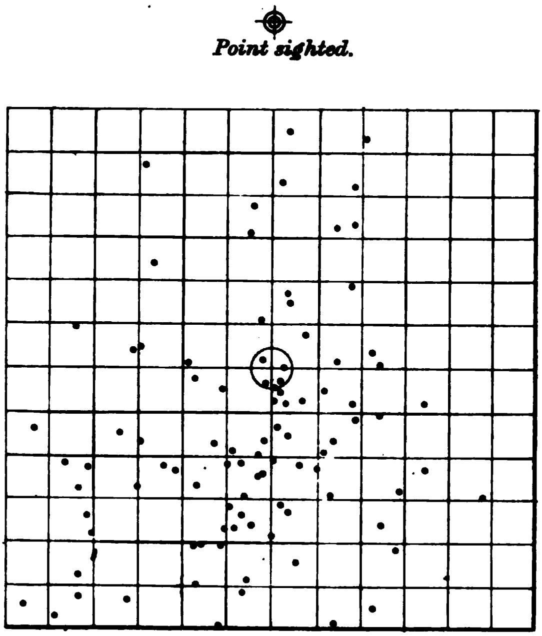
12 feet square.
Distance, 150 yards.
Buckshot Revolver.
Buckshot Cartridges. Charge, 35 grains.
Bullets 10 parts Lead and 1 part Tin.
Point sighted four feet above top and center of Target.
20 Shots. 49 Hits.

Point sighted.



TARGET NO. 17.

12 feet square.
Distance, 150 yards.
Buckshot Revolver.
Buckshot Cartridges. 45 grains.
3 Bullets. Weight of each, 133 grains.
Fired from fixed Rest.
Point sighted 2 feet above top and center of Target.
40 Shots. 95 Hits.



[First indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, June 19, 1878.

Respectfully referred to the commanding officer of National Armory for report.

The pistol and cartridges have this day been sent by express.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

[Second indorsement.]

NATIONAL ARMORY, *August* 13, 1878.

Respectfully returned to the Chief of Ordnance.

The efforts that have been made, heretofore, to render the rifle more effective by substituting multiple or buck shot for a single projectile, for short distances, have not been successful. The "*Shaler sectional bullet*" tried during the late war, in the rifle-musket, was of this class, but did not meet with favor when tried in the field. I am not prepared to say that Captain Wright's cartridge containing three round balls may not under certain circumstances be effective, and if there is any way in which they can be tested in service for the rifle and carbine, I would recommend that a number be issued for this purpose.

The changes proposed, of increasing the weight of the revolver and reducing the number of chambers in the cylinder to enable it to carry the same cartridge as the rifle and carbine, seem to me objectionable and not warranted by the good to be obtained. The revolver being intended for hand-to-hand combat, should, in my opinion, not have long range unless this can be obtained without sacrificing lightness, and without reducing its number of charges.

The pistol and unexpended cartridges will be returned to the Ordnance Office by express to day.

J. G. BENTON,
Lieutenant-Colonel Ordnance, Commanding.

[Third indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, August 15, 1878.

Respectfully returned to the commanding officer of Frankford Arsenal, who will manufacture ten thousand (10,000) of these cartridges for rifle and carbine, and issue them to the commanding officer of San Antonio Arsenal, with explanations, &c., reporting the issue to this office.

The revolver is returned by express.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

[Fourth indorsement.]

FRANKFORD ARSENAL, PA., *September* 9, 1878.

Respectfully returned to the Chief of Ordnance, United States Army.

Ten thousand multiball cartridges, caliber .45, have this day been issued to the commanding officer San Antonio Arsenal.

Attached hereto is a sample of the label put on each box of twenty.

Captain Wright requests that a portion of these cartridges be expended in target practice in addition to the regular allowance so as to allow the men to become familiar with their use.

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

Each cartridge contains three round bullets; these cartridges are intended for *short range* up to 300 yards; they are most effective at from one to two hundred yards, using the ordinary sights of rifle or carbine.

20

MULTIBALL CARTRIDGES,

FOR

SPRINGFIELD RIFLE AND CARBINE,

Cal. .45.

Charge of Powder, 45 Grains. 3 Round Bullets; Weight of each, 133 Grs.

Frankford Arsenal, Sept., 1878.

[Fifth indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, September 12, 1878.

Respectfully referred to the commanding officer of San Antonio Arsenal for his information, and with request for his recommendation how these cartridges should be issued and used to insure the most reliable reports as to their efficiency, &c.

S. C. LYFORD,
Acting Chief of Ordnance.

[Sixth indorsement.]

SAN ANTONIO ARSENAL, *October* 25, 1878.

Respectfully returned to the Chief of Ordnance, United States Army.

The 10,000 multiball cartridges, caliber .45, referred to in the third and fourth indorsements, were received on the 7th instant. For the purpose of obtaining reports on their efficiency and the advisability of further manufacture for issue, I would recommend their issue in equal numbers to the regimental commanders of the four infantry and three cavalry regiments in the Department of Texas, instructions being given for their expenditure in target practice at such ranges and under such circumstances as the officers to whom they are issued may deem most suitable.

CLIFTON COMLY,
Captain of Ordnance, Commanding.

[Seventh indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, November 1, 1878.

Respectfully returned to the commanding officer of San Antonio Arsenal.

Approved.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

[Eighth indorsement.]

SAN ANTONIO ARSENAL,
November 16, 1878.

Respectfully returned to the Chief of Ordnance, United States Army.

The cartridges will be issued on Monday next, the 18th instant, in accordance with the approved recommendation of the sixth indorsement. To the officers there mentioned I have added the commanding officer of the artillery battalion serving at San Antonio, and the commanding officer of the Gatling battery at Fort Clark, feeling confident that these additions will meet with the approval of the department. Attention is respectfully invited to circular letter No. 7, current series, from Headquarters Department of Texas, herewith inclosed. One thousand of the cartridges received will be retained here for such further trial as the reports to be received will probably require.

If practicable I should like to have sent me the altered revolver to which Captain Wright refers in his report. The increased weight, as given, is but little, and while I agree with Colonel Benton as to long range not being specially desirable in the revolver, a weapon intended for hand-to-hand conflict, I am inclined to believe that the loss of one charge in the cylinder, other things being equal, may be more than compensated for by the advantage of the additional number of projectiles given by the multiball cartridge, the chief feature of which, as claimed, is increased efficiency at short ranges.

CLIFTON COMLY,
Captain of Ordnance, Commanding.

REPORT ON MULTIBALL CARTRIDGES FOR SERVICE REVOLVERS.
BY E. M. WRIGHT, CAPTAIN OF ORDNANCE, U. S. A.

(Nine plates.)

FRANKFORD ARSENAL, PA., *December* 13, 1878.

SIR: I had the honor several months ago to submit a report on a Colt's revolver so altered as to use the same multiball cartridge as the rifle and carbine.

The great object in changing the revolver was to obtain *a cartridge for short range that would be interchangeable in* ALL *small-arms and machine guns;* however, as this change would cause considerable outlay, I have since adapted the cartridge to the service revolvers, with a very trifling alteration, and I now submit the following report of what has been accomplished in this direction.

As the chamber of the service Colt is longer than that of the Smith and Wesson, I have made a cartridge which can be used in either, and another which can only be used in the Colt.

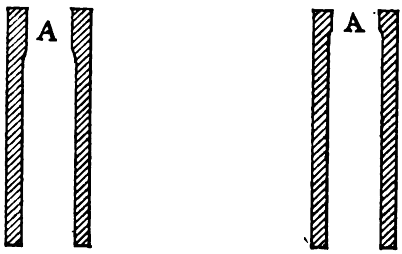
The former contains two and the latter three balls. I will, therefore, designate them two and three ball cartridges.

With the two-ball cartridges *no change whatever will have to be made in the present service Colt's revolver.*

This cartridge, however, does not develop the full power of the weapon, and the alterations required to adapt it to the three-ball cartridge are very trifling.

The chambers of both revolvers are now choked at the forward end in order to prevent the bullets of unfired cartridges, especially the uncrimped ones, from advancing when the revolver is fired (see Fig. 1), preventing the rotation of the chamber, and also to prevent escape of gas at the joint of chamber and barrel.

No. 1. No. 2.



Drawings exaggerated to show choke of chamber.

By reaming out the chamber a little more, still leaving sufficient choke to prevent any escape of gas (see Fig. 2), the Colt will readily take a three-ball cartridge containing sufficient powder to render it a very effective weapon even beyond 100 yards.

The chamber of the Smith and Wesson is entirely too short for a three-ball cartridge.

Having found by experiments with the multiball cartridge that the front bullet is the most accurate of the three, I have, for the purpose of spreading the other bullets at short range, from the revolver, reduced them in diameter slightly, so that while they take the rifling, their stability of rotation is less and they spread more.

In this report will be found targets, &c., at different distances with the following cartridges:

No. 1. Three ball, bullets of same size, 20 grains rifle powder.

No. 2. Three ball, bullets of same size, 22 grains Dupont powder.

No. 3. Three ball, two rear bullets smaller than front one, 25 grains rifle powder.

No. 4. Two ball, bullets of same size, 25 grains rifle powder.

No. 5. Two ball, rear bullets smaller than front one, 25 grains rifle powder.

The amount of "spread" of the different bullets can be controlled readily, by varying the four variables in the cartridges, *i. e.*, the amount and kind of powder, and the size and hardness of the bullets used, the front one in all cases going straight to the mark.

I have used in part of my experiments an old rifle powder made many years ago, and of which we have on hand at this arsenal 45 barrels.

This powder gives with the rifle-cartridge a velocity of 1,390 feet. The Du Pont powder used in No. 2 cartridge is service musket, giving a velocity of 1,375 feet.

The bullets used were made of the usual bullet metal, *i. e.*, lead 16, tin 1.

Any of these cartridges can be readily made with the present machinery.

Their penetration is sufficient, and the recoil about the same as with the service cartridge.

The Colt's with the "three-ball" cartridge would be considerably more than twice as effective a weapon as at present, and the Smith & Wesson with a "two-ball" cartridge would be vastly improved.

Sample cartridges accompany this report. The following is the record:

Recoils.

Colt's revolver: ammunition No. 1, 23 pounds; No. 2, 27 pounds; No. 3, 24 pounds.

Service ammunition, both revolvers, 21 pounds; Smith & Wesson revolver, Nos. 1 and 2, 21 pounds.

Penetration, in pine boards.

Distance, 25 yards; No. 1, 1⅝ inches; No. 2, 1⅞ inches; No. 3, 1½ inches; No. 4, 1½ inches; No. 5, 1½ inches.

Distance, 100 yards; No. 1, 1⅛ inches; No. 2, 1⅛ inches; No. 3, ⅝ inch; No. 4, 1⅛ inches; No. 5, ¾ inch.

I would respectfully request an authoritative competitive trial of all the revolvers for multiball cartridges, with their different ammunitions, and would suggest that the improvised fixed rest now at this arsenal could be sent anywhere for the purpose of the trial.

Very respectfully, your obedient servant,

E. M. WRIGHT,
Captain of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.
(Through the commanding officer.)

[Indorsement.]

FRANKFORD ARSENAL, *December* 16, 1878.

Respectfully forwarded to the Chief of Ordnance, U. S. A.

From actual firing I am satisfied as to the efficiency of the three-ball cartridge for the Colt's revolver at short ranges with a charge of 20 grains of powder. The alteration in the choke of the chamber seemed to do no harm. I concur with Captain Wright in his request.

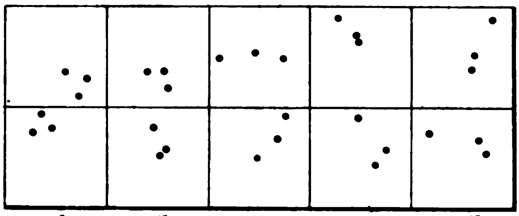
JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

Targets 1 foot square.

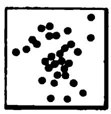
Distance, 25 yards.

Ammunition No. 1.

1st. Shot. 2nd. 3rd. 4th. 5th.



6th. 7th. 8th. 9th. 10th.

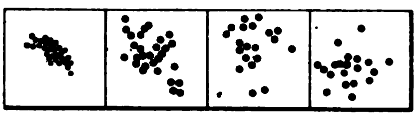


30 Hits.

Above shots consolidated.

Ammunition.

No. 2. No. 3. No. 4. No. 5.



10 shots. 30 hits. 10 s. 29 h. 10 s. 20 h. 10 s. 20 h.

Data.

Where bullets are of different sizes,

• *Front bullet.*

• *Rear bullets.*

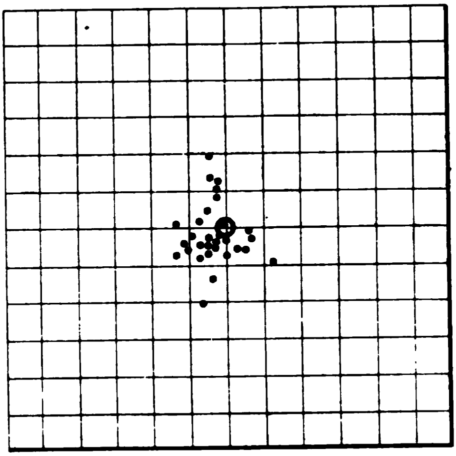
TARGET

12 feet square.

Distance, 50 yards.

Ammunition. No. 1.

10 Shots. 30 Bullets. 30 Hits.



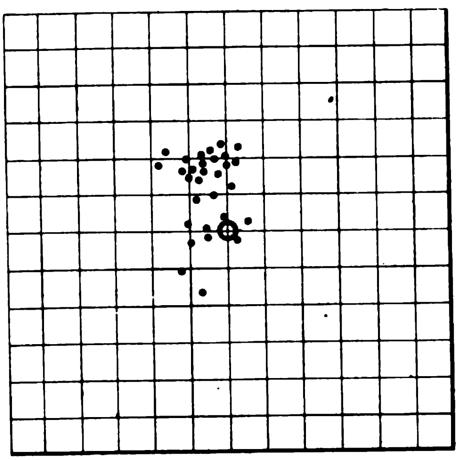
TARGET

12 feet square.

Distance, 50 yards.

Ammunition. No. 2.

10 Shots. 30 Bullets. 30 Hits.



⊕ *Point sighted, center of Target.*

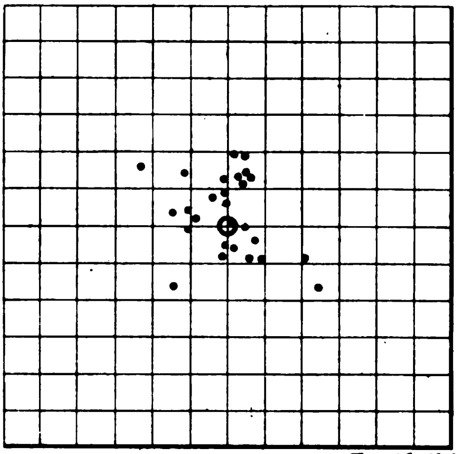
TARGET

12 feet square.

Distance, 50 yards.

Ammunition No. 3.

10 Shots. 30 Bullets. 27 Hits.



• *Front bullet.*
• *Rear bullets.*

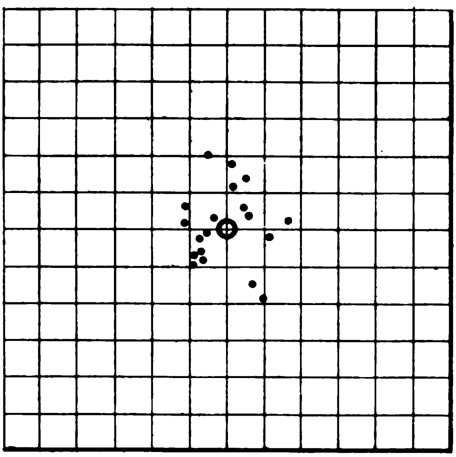
TARGET

12 feet square.

Distance, 50 yards.

Ammunition No. 4.

10 Shots. 20 Bullets. 19 Hits.



⊕ *Point sighted, center of Target.*

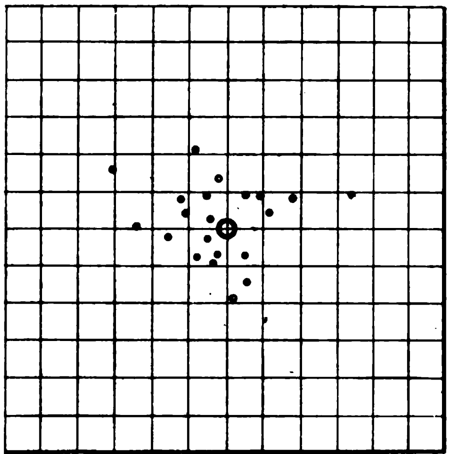
TARGET

12 feet square.

Distance, 50 yards.

Ammunition No. 5.

10 Shots. 20 Bullets. 20 Hits.



• *Front bullet.*
• *Rear bullets.*

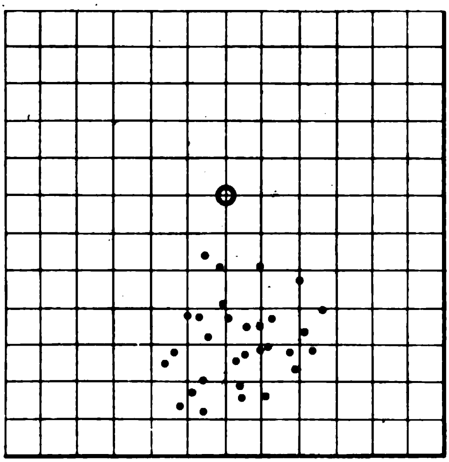
TARGET

12 feet square.

Distance, 75 yards.

Ammunition No. 1.

10 Shots. 30 Bullets. 30 Hits.



⊕ *Point sighted.*

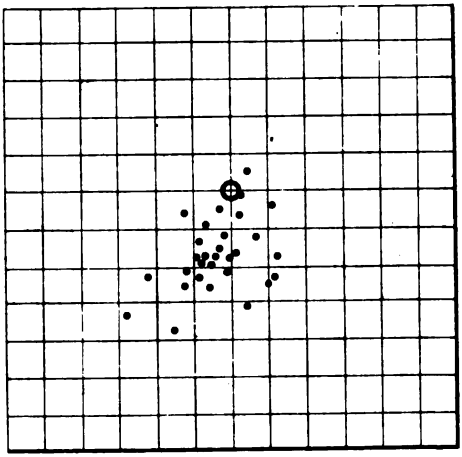
TARGET

12 feet square.

Distance, 75 yards.

Ammunition No. 2.

10 Shots. *30 Bullets.* *30 Hits.*



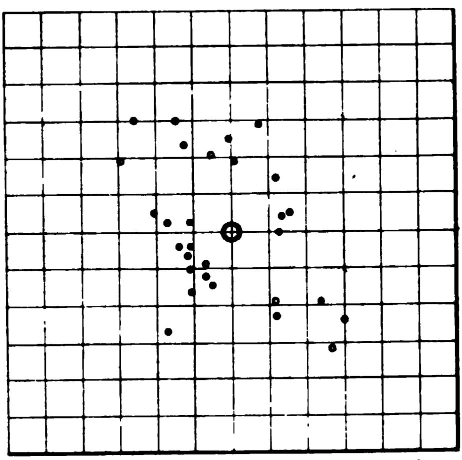
TARGET

12 feet square.

Distance, 75 yards.

Ammunition No. 3.

10 Shots. *30 Bullets.* *29 Hits.*



Point sighted.

• *Front bullet.*
• *Rear bullets.*

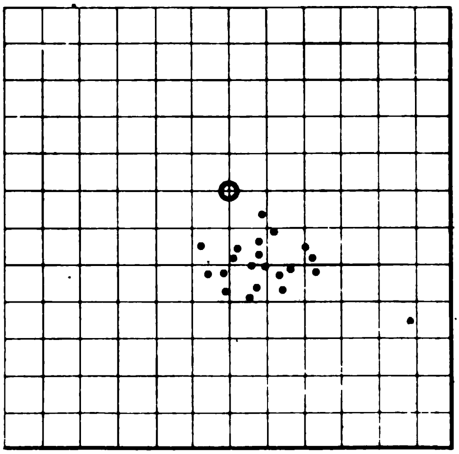
TARGET

12 feet square.

Distance, 75 yards.

Ammunition No. 4.

10 Shots. *20 Bullets.* *20 Hits.*



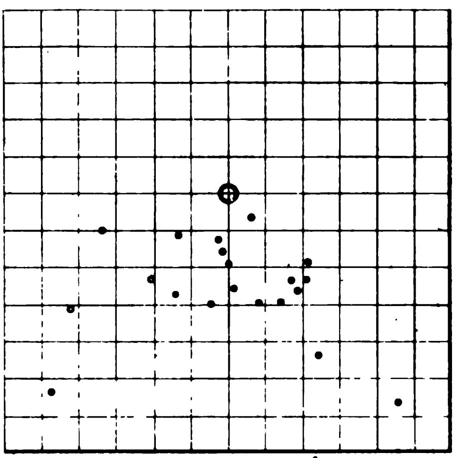
TARGET

12 feet square.

Distance, 75 yards.

Ammunition No. 5.

10 Shots. *20 Bullets.* *20 Hits.*



⊕ *Point sighted.*

• *Front bullet.*
• *Rear bullets.*

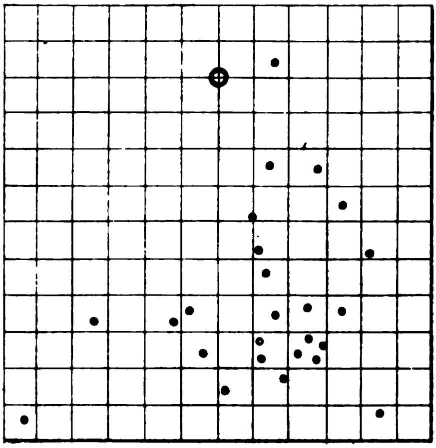
TARGET

12 feet square.

Distance, 100 yards.

Ammunition No. 1

10 Shots. *30 Bullets.* *25 Hits.*



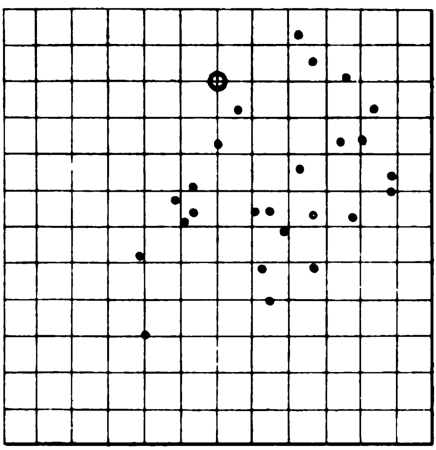
TARGET

12 feet square.

Distance, 100 yards.

Ammunition No. 2.

10 Shots. *30 Bullets.* *25 Hits.*



Point sighted.

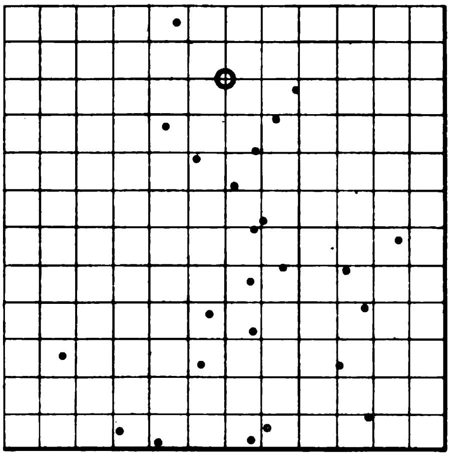
TARGET

12 feet square.

Distance, 100 yards.

Ammunition No. 3.

10 Shots. 30 Bullets 24 Hits.



• *Front bullet.*
• *Rear bullets.*

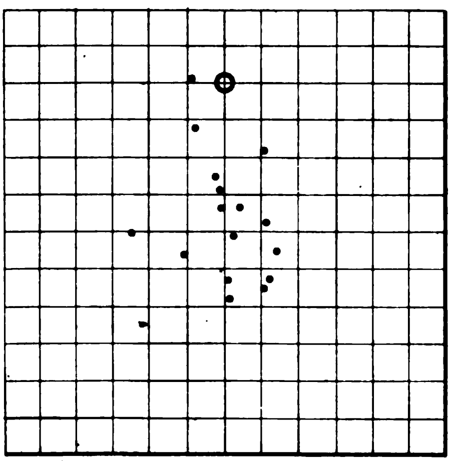
TARGET

Distance, 100 yards.

Twelve feet square.

Ammunition No. 4.

10 Shots. 20 Bullets. 16 Hits.



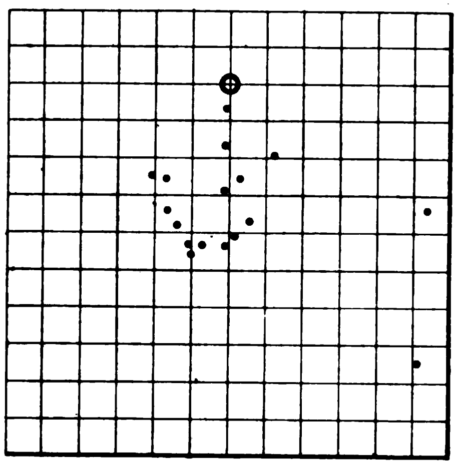
⊕ *Point sighted.*

TARGET

Distance, 100 yards.
Twelve feet square.

Ammunition No. 5.

10 Shots. *20 Bullets* *17 Hits.*



Point sighted.

• *Front bullet.*
• *Rear bullets.*

[Indorsements.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, December 19, 1878.

Respectfully referred to the commanding officer of the National Armory for report, and with directions to call upon the commanding officer of Frankford Arsenal for such cartridges as he may need.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

NATIONAL ARMORY, *June* 5, 1879.

Respectfully returned to the Chief of Ordnance with the report of Captain Greer, Ordnance Department, herewith inclosed.

J. G. BENTON,
Lieutenant-Colonel, Commanding.

NATIONAL ARMORY,
Springfield, Mass., June 4, 1879.

SIR: In accordance with your instructions, I have the honor to sub mit the following report on the multiball cartridges for Army revolvers, devised by Captain Wright, Ordnance Department:

These cartridges were tested for initial velocity, recoil, power—as shown by penetration in white pine—accuracy, and dispersion of fire. The velocities, it will be seen, are somewhat lower than that of the service cartridge, but the weight of lead thrown is so much greater than in the service as to give with Nos. 2 and 3 an unpleasant shock to the hand and arm.

In power there is a decided lack as compared with the service cartridge, Nos. 2 and 3 giving but one inch and 4 and 5 two inches penetration at 25 yards. No. 4 falls off to 1.25 and No. 5 to 1.8 inches at 50 yards.

A penetration of 1 inch in white pine is usually considered as corresponding to a dangerous wound; but this presupposes that the bullet has some weight, as, for example, the rifle bullet of 405 grains, or perhaps even the revolver bullet of 230 grains. The shock to the system is an element as well as the mere penetration. The weight of these bullets is from 117 to 130 grains.

As regards accuracy, two considerations are involved, viz, uniformity of dispersion and the coincidence of the centers of the clusters of shot-holes produced at each shot. Both these are necessary in order always to insure the same effect at a given range. The deviations are given in the table, and the 10 centers of impact of the 30 and 20 bullets are platted in comparison with 10 shots made with the service cartridge. Except at very short ranges, the accuracy cannot be considered satisfactory.

With regard to dispersion of fire, which is the true *raison d'être* of these cartridges, an inspection of the tables shows that at short ranges there is none at all, the bullet-holes of each shot nearly coinciding. At longer ranges, 75 and 100 yards, there is a considerable dispersion of balls, but they have too little power to do much execution.

Again, the weight of the cartridges carried is to be considered. The table shows an increase in the weight of 60 cartridges over 60 of the service of from 2.2 ounces in No. 5 to 1 pound 8 ounces in No. 2.

Lastly, the use of these cartridges necessitates a slight change in the chambers of every revolver in the service unless the two-ball cartridge be fired from the Colt, which, however, was not intended, as it was desired to utilize its longer cylinder for the three-ball cartridge.

As a result of the tests, it may be stated that these cartridges are inferior to the service, which is lighter, more accurate, and far more powerful, giving a penetration of 2.25 inches at 300 yards.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A.

The COMMANDING OFFICER,
National Armory.

Velocities and recoil.

Revolver.	Weight of revolver.	Cartridges.	Kind of powder.	Weight of powder.	Weight of bullets.	No. of bullets.	* Velocities by Le Boulengé chronograph.	Recoil, theoretical.
				Grs.	*Grs.*		*Feet.*	*Ft. lbs.*
Colt's	16,710 grains	Service	Service	28	230	1	730	†3.75
		No. 2	Du Pont	22	390	3	597.6	7.22
		No. 3	Rifle	25	352	3	663.2	7.24
Smith & Wesson	17,207 grains	No. 4	do	25	260	2	563.9	2.77
		No. 5	do	25	240	2	691	3.55

* Mean of several shots.

† Quantity of motion of revolver equals that of projectile, or $MV = mv$, and

Quantity of work of recoil, or $Q = \frac{MV^2}{2} = \frac{m^2v^2}{2M} = \frac{w^2v^2}{2gW}$

$$\frac{\frac{230^2}{7000^2}\,730^2}{64.32\,\frac{16710}{7000}} = \frac{230^2 \times 730^2}{64.32 \times 7000 \times 16710}$$

Hence,

$$\text{Log. } Q = 2 \text{ log. } 230 + 2 \text{ log. } 730 - \text{log. } 64.32 - \text{log. } 7000 - \text{log. } 16710.$$
$$Q = 3.75 \text{ foot-pounds.}$$

Weights of cartridges.

Number of cartridges.	Service.	No. 2.	No. 3.	No. 4.	No. 5.
	Lbs. Oz.	*Lbs. Oz.*	*Lbs. Oz.*	*Lbs. Oz.*	*Lbs. Oz.*
60	2 13.5	4 4.8	4 2.2	3 1.5	2 15.7

Penetration in white pine.

Distance.	Service.	*No. 2.	*No. 3.	No. 4.	No. 5.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
25 yards	5.75	1	1	2	2
	5.75	1	1	2	2
	5.1	1	1	2	2
	5.75	1	1	1.75	1.5
	5.1	1	1	1.75	2
	5.5	1	1	2	2
Mean	5.49	1	1	1.9	1.9
50 yards	4	1	1	1.25	1.75
	4.75	1	1	1.25	1.75
	5.25	1	1	1.25	1.75
	4.25	1.25	1	1.25	1.75
	5.75	1	1	1.25	1.75
	4.8	1	1	1.25	2
Mean	4.8	1.04	1	1.25	1.79
75 yards	4	1	1	1.25	1.25
	4.4	1	1	1.25	1.25
	4.25	1	1	1.25	1.25
	4.75	1	1.25	1.25	1.25
	4.75	1	1	1.00	1.25
	4.25	1	1	1.25	1.25
Mean	4.4	1	1.04	1.21	1.25
100 yards	3.75	1	1	1.25	1.25
	4.5	1	1	1.25	1.25
	3.5	1	1	1.25	1.25
	4.1	1	1	1	1.25
	4.1	1	1	1	1.25
	4	1	1	1.25	1.25
Mean	3.99	1	1	1.16	1.25

*Penetration butts are made of inch boards with spaces of one inch between boards. While it is probable that the balls had a little more force at 25 than at 100 yards, there was not enough difference to cause them to enter the second board.

Accuracy.

25 YARDS.

Cartridges.	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.
	Inches.	*Inches.*	*Inches.*
Service	1.04	2.2	2.48
No. 2	6.8	4.6	8.2
No. 3	3.7	2.2	4.3
No. 4	2.05	2.07	2.91
No. 5	1.5	1.7	2.4

50 YARDS.

Service	4	2.7	4.83
No. 2	7.56	9.87	12.4
No. 3	8.37	7.5	11.2
No. 4	5.55	4.03	6.86
No. 5	5.74	5.16	7.72

75 YARDS.

Cartridges.	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.
Service	3.08	5.88	6.64
No. 2	11	17.4	20.6
No. 3	17.5	16.4	24
No. 4	26.5	16.1	31
No. 5	13.1	18.5	22.7

100 YARDS.

Cartridges.	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.
Service	5.1	2.8	5.82
No. 2	19.6	17.4	26.2
No. 3	21.4	15.7	25.5
No. 4	17.5	12.1	21.3
No. 5	18.4	14.3	23.3

Target record at 25 yards.

Number of shot.	Cartridges.															
	No. 2.				No. 3.				No. 4.				No. 5.			
	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
	12	....	2	....	10	....	....	1	12	....	....	8	7	....	....	2
1	12	....	2	....	5	....	....	2	12.5	....	....	8	8	....	....	3
	11	....	4	....	4	....	....	3	....	....	....	....	....	....	....	....
	12	....	....	12	7	....	....	14	13	....	....	4	8	....	....	10.5
2	12	....	....	14	6	....	....	9	11	....	....	5	5	....	....	5
	13	....	....	14	5	....	....	6	....	....	....	....	....	....	....	....
	15	....	....	5	4	....	....	4	9	....	....	4	5	....	....	2
3	17	....	....	5	5	....	....	4	8.5	....	....	4.5	6	....	....	3
	18	....	....	6	5	....	....	8	....	....	....	....	....	....	....	....
	18	....	....	9	9	....	3	....	9	....	....	5	6	....	....	2
4	19	....	....	4	9	....	1	....	9	....	....	5.5	7	....	....	3
	20	....	....	4	4	....	....	8	....	....	....	....	....	....	....	....
	19	....	....	5	12	....	....	2	9	....	....	6	4	....	....	4
5	20	....	....	7	1	....	....	3	6.5	....	....	3	2	....	....	5
	20	....	....	8	1	....	....	8	....	....	....	....	....	....	....	....
	19	....	....	9	5	....	....	6	6	....	....	3.5	2	....	....	5
6	23	....	....	11	5	....	....	7	6	....	....	4	2	....	....	1
	27	....	....	10	5	....	....	14	....	....	....	....	....	....	....	....
	4	....	....	18	9	....	3	....	7	....	....	7	1	....	....	3
7	6	....	....	19	8	....	8	....	7	....	....	7.5	3	....	....	3
	14	....	....	19	4	....	....	5	....	....	....	....	....	....	....	....
	19	....	....	19	10	....	....	1	7	....	....	8	6	....	....	2
8	20	....	....	19	5	....	....	2	6.5	....	....	8	5	....	....	2
	20	....	....	17	4	....	....	2	....	....	....	....	....	....	....	....
	20	....	....	17	1	....	....	1	5.5	....	....	7	2	....	....	2
9	19	....	....	17	6	....	....	1	5	....	....	9	3	....	....	3
	28	....	....	26	11	....	....	10	....	....	....	....	....	....	....	....
	25	....	....	27	6	....	....	5	5	....	....	11	4	....	0	....
10	27	....	....	29	6	....	....	7	5	....	....	12	0	....	1	....
	33	....	....	13	7	....	....	8	....	....	....	....	....	....	....	....

Target record at 50 yards.

Number of shot.	Cartridges.															
	No. 2.				No. 3.				No. 4.				No. 5.			
	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
	8			7	8			7	11			8	1			6
1	8			14		2		13	9			7		5	8	
		2		16	2			24								
	17			3	2			18		1		3		1		2
2	5			13	13			6	7			7	6			5
		1		42	12			12								
	13			8		1	5		0			10		7		4
3	7			7	18		19		8		2		2		5	
	6		22		8			10								
	17			14		5	1			4		1	14		1	
4	17			15	5			13	10			6	6		2	
		6		7	10		7									
		1		5		4		23	5			8	6		1	
5	11			7		2		24	9			17	25			20
	20			14	32			18								
	1		5		0			18	12		4			0		1
6	6			1	11			2	4			6		0	2	
	4			28	13			6								
	13			13		4	7		5		5			1		1
7	5			16	16		2		5		4		6			14
	5			25	6			9								
	14			2	5			10	4			11		2	5	
8	13			13		2		9		7	10		5			7
	2			17	22			8								
	23			13	1			10	4		8		3		0	
9	17			9	7			15	10			6	1		7	
	9			12	28		12				4					
	26			2	2			15	10			7		3		0
10	5			9	6		4		10			0	10			18
	1			31	6			11								

Target record at 75 yards.

Number of shot.	Cartridges.															
	No. 2.				No. 3.				No. 4.				No. 5.			
	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
	18			8		11	6			26	16			19		19
1		6		19	19			31		43	4			15		22
		23		24	40			17								
		1		40	6			8		Miss.				3		7
2	10			24		6		25		5	49		9		7	
	20			19	50		22									
		49	4		11			4		10	27			2		8
3		27		39		5		22		16		35	31		4	
	35			21		21		6								
	0			10		11		21		7	50			11	8	
4	30			2	6			28		23		19		13		7
	28			26	28			7								
	9			22		1		22	10			8		Miss.		
5	9			21	4			20		2		34	10			1
		2		22	17			64								
	39			22	22			23	14		27		23			9
6	29			30	16			25		8		29	28			12
		6		2		32		26								
	31			2	13			12	14			13		24	11	
7	13			22	10			14	18		23			29		21
	24			18		Miss.										
	0		18			12		9	43		14			3		7
8		8		13	20			2	36		34			20	8	
	30			34	29		18									
		26		25		13	10			4	4		22			6
9	8			16		10		5	10			41	25			43
		8	6			5	50									
	2			14		11		22		22		12	11			33
10	2			28		40		68	20			70	6			51
	52			58		10		69								

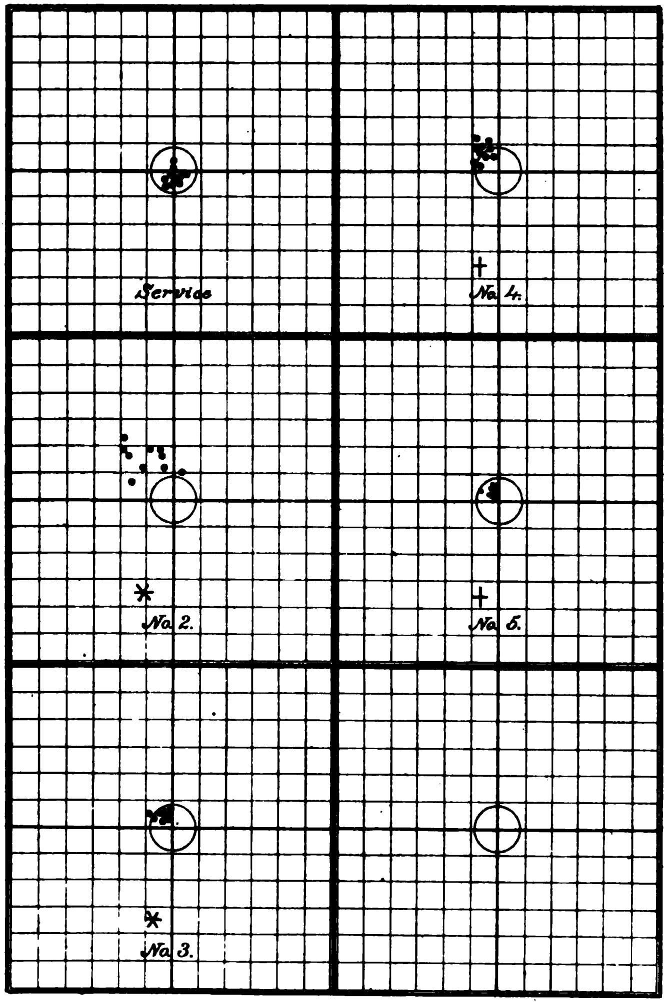
Target record at 100 yards.

Number of shot.	Cartridges.															
	No. 2.				No. 3.				No. 4.				No. 5.			
	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
1	....	18	....	17	....	18	....	20	....	7	....	38	....	27	....	26
	....	13	....	28	....	16	....	24	....	19	....	56	....	26	....	51
	Miss.				....	47	41	....	....	....	....	....	....	....	....	....
2	25	....	13	....	....	7	....	21	....	18	....	6	....	6	32	....
	....	10	5	....	....	2	....	44	....	9	....	22	....	28	3	....
	5	....	....	33	....	27	....	83	....	....	....	....	....	....	....	....
3	....	1	16	....	....	13	10	....	....	27	10	....	....	5	....	13
	....	9	17	....	....	46	6	....	....	19	25	....	5	....	....	30
	....	8	....	32	20	....	....	21	....	....	....	....	....	....	....	....
4	30	....	8	....	....	6	43	....	....	23	....	16	....	29	....	20
	....	4	....	18	....	8	....	15	....	51	....	6	....	51	....	27
	....	62	20	....	....	20	....	25	....	....	....	....	....	....	....	....
5	7	....	....	27	7	....	47	....	....	34	....	18	7	....	7	....
	5	....	....	30	....	21	....	13	....	38	....	40	....	45	....	48
	24	....	....	60	....	70	....	9	....	....	....	....	....	....	....	....
6	....	0	....	4	13	....	0	....	....	10	....	44	....	30	....	19
	12	....	....	52	....	15	....	7	....	28	....	41	....	40	....	39
	....	28	....	39	....	37	52	....	....	....	....	....	....	....	....	....
7	4	....	....	35	2	....	....	19	11	....	....	26	1	....	....	6
	....	24	....	40	....	20	....	25	....	31	....	20	....	16	....	19
	....	53	....	20	....	7	....	45	....	....	....	....	....	....	....	....
8	Miss.				0	....	....	36	....	42	....	18	....	5	4	....
	....	5	5	....	16	....	....	40	....	8	....	62	....	24	....	26
	....	20	8	....	....	8	....	23	....	....	....	....	....	....	....	....
9	1	....	....	42	14	....	....	10	....	5	....	11	....	11	....	25
	....	11	....	16	....	4	....	38	....	41	....	42	....	38	....	50
	....	43	....	10	10	....	....	46	....	....	....	....	....	....	....	....
10	71	....	....	40	....	....	....	....	....	16	....	41	....	8	....	2
	....	8	....	7	....	....	....	....	Miss.				....	13	23	....
	....	6	....	46	....	....	....	....	....	....	....	....	....	....	....	....

TARGETS

12 feet square.

Distance, 25 yards.



* *Centers of impact of the 3 bullets of each shot, or the 10 centers of the 30 bullets.*

+ *Centers of impact of the 2 bullets of each shot, or the 10 centers of the 20 bullets.*

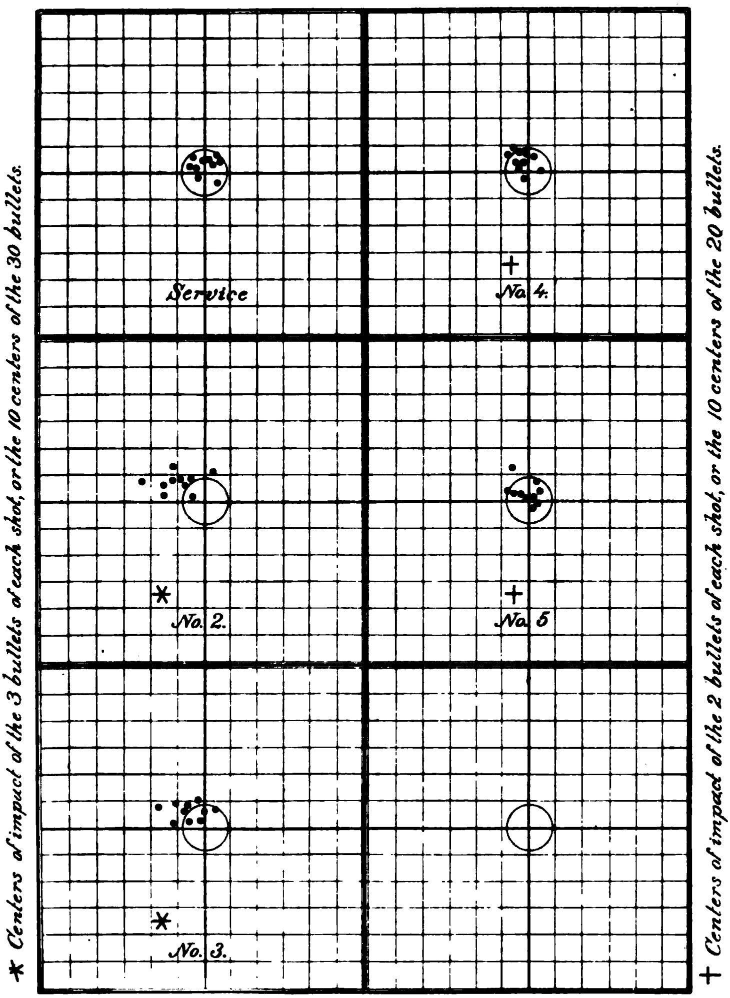
Point sighted, center of Target.

Fired from Muzzle Rest.

TARGETS

12 feet square.

Distance, 50 yards.

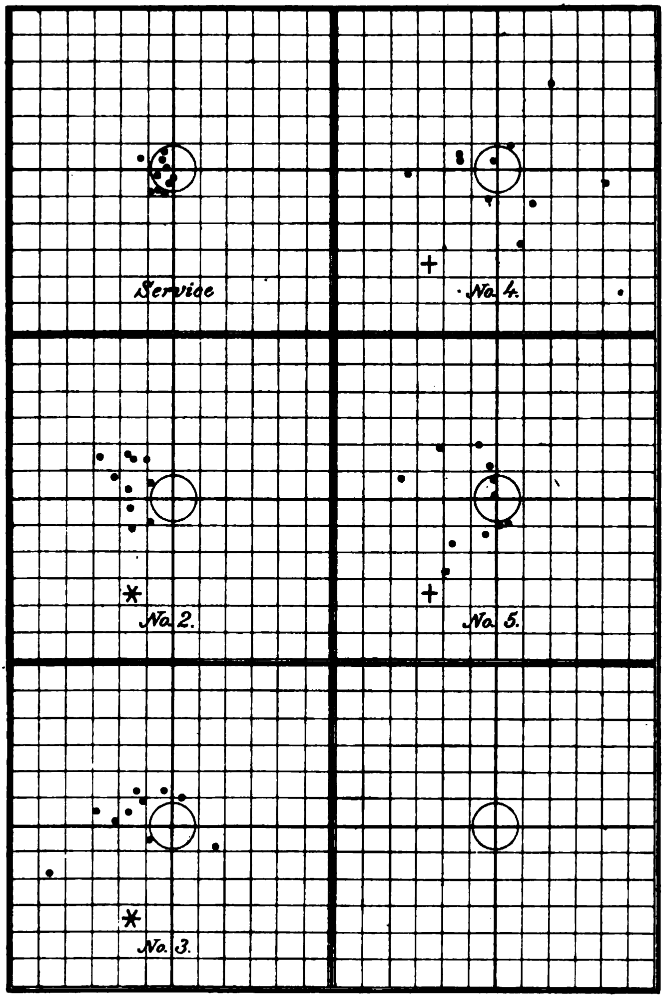


Point sighted, center of Target.

Fired from Muzzle Rest.

TARGETS

12 feet square.
Distance, 75 yards.



✱ *Centers of impact of the 3 bullets of each shot, or the 10 centers of the 30 bullets.*

+ *Centers of impact of the 2 bullets of each shot, or the 10 centers of the 20 bullets.*

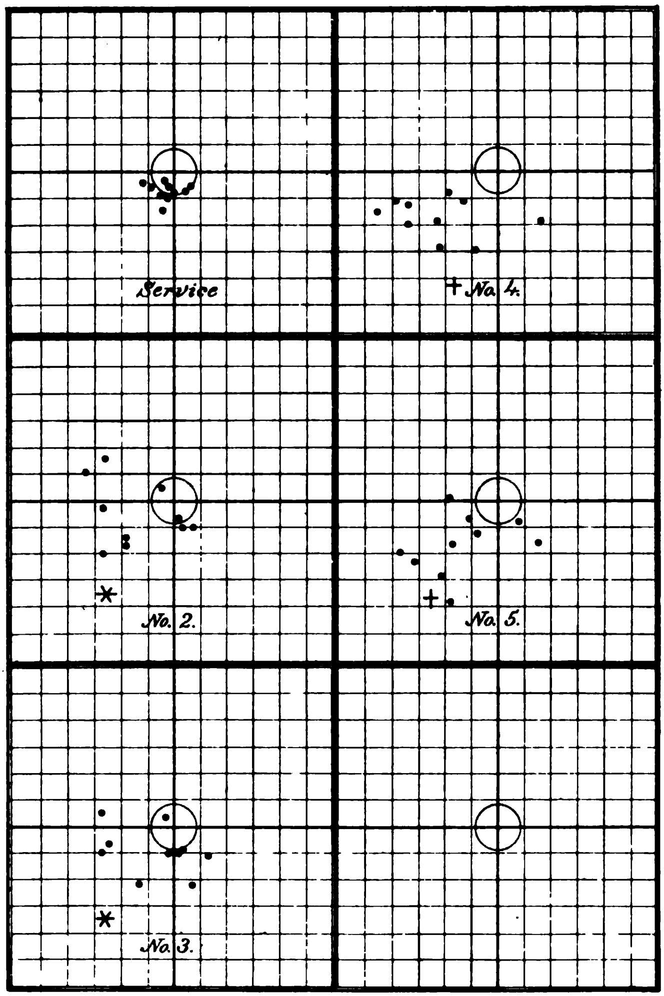
Point sighted center of Target.

Fired from Muzzle Rest.

TARGETS

12 feet square.

Distance, 100 yards.



✱ *Centers of impact of the 3 bullets of each shot, or the 10 centers of the 30 bullets.*

+ *Centers of impact of the 2 bullets of each shot, or the 10 centers of the 20 bullets.*

Point sighted, center of Target.

Fired from Muzzle Rest.

[Indorsements.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, June 9, 1879.

Respectfully returned to Capt. E. M. Wright, through the commanding officer of Frankford Arsenal.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

FRANKFORD ARSENAL, PA., *June* 23, 1879.

Respectfully returned to the Chief of Ordnance, U. S. A., through the commanding officer, Frankford Arsenal.

I cannot agree to the conclusions drawn by Captain Greer in his report.

I consider a penetration equal to one inch in white pine, with a bullet weighing 117 grains, would produce a dangerous wound. The buckshot from the old "buck and ball" cartridge weighed but 41 grains, and was deemed effective. The efficiency of the multiball cartridge would be more fully proved if fired under service conditions. It is one thing to fire a revolver "with a muzzle rest"; it is a very different affair to fire it while mounted.

E. M. WRIGHT,
Captain of Ordnance, U. S. A.

FRANKFORD ARSENAL, PA., *June* 24, 1879.

Respectfully returned to the Chief of Ordnance, U. S. A.

I am convinced that for ranges varying from 25 to 100 yards the disabling effect of the service revolver is doubled or trebled fired with the multiball cartridge. This I understand is about what is claimed for it, and nothing more.

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

ORDNANCE OFFICE, *June* 25, 1879.

Respectfully referred to commanding officer, National Armory, inviting his attention to fourth and fifth indorsements.

The recent equipment board was "so impressed with the value of this kind of ammunition that it recommended that it be manufactured and adapted to the Army revolver." Our trials and experiments must settle the question first and prove that the expense of alteration of revolvers, &c., is justified by the success of our trials. Please give it further con-

S. V. BENÉT,
Brigadier-General and Chief of Ordnance.

NATIONAL ARMORY, *July* 15, 1879.

Respectfully returned to the Chief of Ordnance.

Out of regard to the recommendation of the board referred to in the sixth indorsement, I would recommend that a thorough trial of Captain Wright's multiball cartridge be made in the field, with the service revolver, Colt's pattern.

With regard to the use of buckshot, and ball and buckshot cartridges, to which Captain Wright refers in the fourth indorsement, the former was practically abandoned more than thirty years ago for the want of efficiency in the military service. I also recollect that military men very much doubted the usefulness of the ball and buckshot cartridge, consid-

ering that buckshot wounds from these cartridges were of rare occurrence.

J. G. BENTON,
Colonel Commanding.

ORDNANCE OFFICE, *July* 18, 1879.

Respectfully returned to commanding officer, Frankford Arsenal, who will get up a multiball cartridge for the Colt's *service* revolver and send a sample to this office.

S. V. BENÉT,
Brigadier-General and Chief of Ordnance.

FRANKFORD ARSENAL, PA., *July* 19, 1879.

Respectfully referred to Capt. E. M. Wright for compliance with preceding indorsements.

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

FRANKFORD ARSENAL, *August* 25, 1879.

Respectfully returned to the commanding officer, with inclosed report and sample.

E. M. WRIGHT,
Captain of Ordnance, U. S. A.

REPORT.

FRANKFORD ARSENAL, *August* 25, 1879.

SIR: I have the honor to submit herewith a sample multiball cartridge adapted to the "service Colt's revolver."

To obtain sufficient length of case, and to overcome the choke of the chamber, I have bottled the case slightly at the forward end.

This allows the use of three bullets, diameter ".428; weight, 110 grains; charge of powder, 25 grains.

This cartridge is sufficiently accurate, and gives good penetration.

The latter is as follows:

25 yards, 2 inches.
50 yards, 1½ inches.
75 yards, 1¼ inches.
100 yards, 1 inch.

I had hoped to compare the destructive effect of the service and multiball cartridge by firing while mounted. This was found to be impracticable, and as the next best thing two targets were made on foot, running. Starting at 100 yards on a gentle run, the revolver was fired till empty. It was then reloaded at a halt, and running and firing resumed. In this manner the target was approached 20 yards at a time, the average time for this distance being ten seconds.

There being but twelve multiball cartridges left, I commenced the sixth chamberful of each cartridge at 50 yards, and the seventh at 25 yards. The target was 6 feet high and 16 feet long. On this were rudely drawn the figures of eight men.

The accompanying targets show the results.

I also inclose herewith sample of the bullet after striking an iron target; distance, 75 yards.

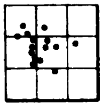
Very respectfully, your obedient servant,

E. M. WRIGHT,
Captain Ordnance, U. S. A.

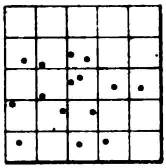
COMMANDING OFFICER, *Frankford Arsenal.*

SERVICE COLT'S REVOLVER. MULTIBALL CARTRIDGE

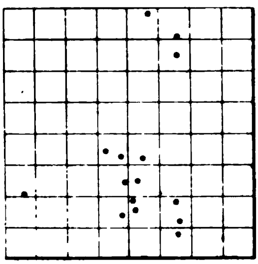
Target 3 feet square. Distance 25 yards.
5 Shots. 15 Hits.
Penetration 2"



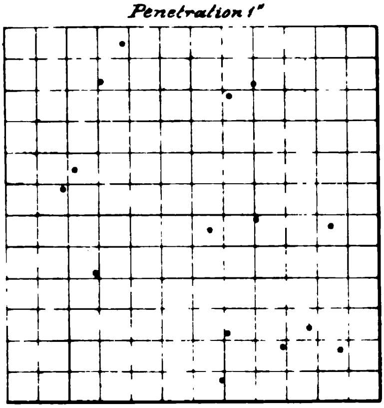
Target 5 feet square. Distance 200 yards.
5 Shots. 15 Hits.
Penetration 1½"



Target 8 feet square. Distance, 50 yards.
5 Shots. 15 Hits.
Penetration 1¼"



Target 12 feet square. Distance, 75 yards.
5 Shots. 15 Hits.
Penetration 1"



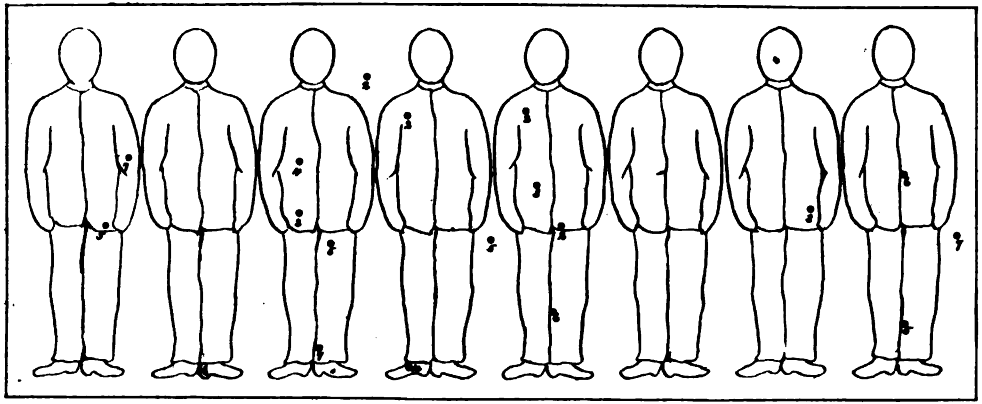
Note.

Fired from fixed Rest.

SERVICE COLT'S REVOLVER. MULTIBALL CARTRIDGE

FIRED RUNNING, COMMENCING AT 100 YARDS FROM TARGET.

First Six Shots	*Distance from Target*	*100*	*to 80 yards.*
Second	"	*80*	" *60* "
Third	"	*60*	" *40* "
&c.		*&c.*	*&c.*
Sixth	"	*50*	" *25* "
Seventh	"	*25*	" *0* "



Numbers near shot marks indicate the series of 6 shots to which this particular shot belongs.

Record.

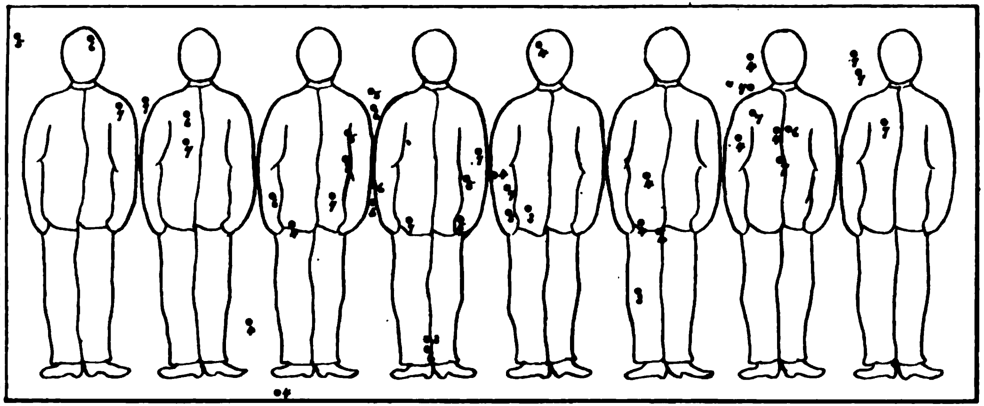
	Figures hit.	No. of hits.	Total hits in target.
1st. Six Shots.	0	0	0
2nd " "	2	3	4
3rd " "	3	3	3
4th " "	2	2	2
5th " "	2	2	3
6th " "	2	2	2
7th " "	2	2	3
42 Shots.	13	14	17

The aim for the first 6 shots was probably too high. Shots were heard to hit iron screen nearly 100 yards in rear of target.

SERVICE COLT'S REVOLVER. MULTIBALL CARTRIDGE

FIRED RUNNING COMMENCING AT 100 YARDS FROM TARGET.

First Six Shots	*Distance from Target*	100	to 80 yards.
Second	"	80	" 60 "
Third	"	60	" 40 "
&c.		&c.	&c.
Sixth	"	50	" 25 "
Seventh	"	25	" 0 "



Record.

	Figures hit.	*No. of hits.*	*Total hits in target.*
1st. Six Shots	0	0	0
2nd. " "	0	0	0
3rd. " "	3	3	3
4th. " "	4	8	10
5th. " "	3	4	7
6th. " "	5	5	7
7th. " "	7	9	13
42 Shots	22	29	40

Aim at first was too high. Shots went over target and struck iron screen nearly one hundred yards in rear.

Numbers near shot marks indicate the series of 6 shots to which this particular shot belongs.

[Indorsements.]

FRANKFORD ARSENAL, *August* 25, 1879.

Respectfully returned to Captain Wright for further explanation as regards space occupied by the sample cartridge, as to length of chamber of revolver, and practicability of manufacture by the quantity in ordinary loading machines.

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

FRANKFORD ARSENAL, *August* 26, 1879.

Respectfully returned to commanding officer.

The length of the chamber of the Colt's revolver is 1″.6. The total length of the sample multiball cartridge is 1″.61. Deducting ″0.6 for thickness of head, as the cartridge-head occupies no part of the chamber, leaves the length of chamber taken up by the cartridge 1″.55. The front bullet is therefore ″0.5 below the front face of the chamber. There would be no trouble in the manufacture of this cartridge in quantity by the ordinary machine now in use at this arsenal.

E. M. WRIGHT,
Captain of Ordnance, U. S. A.

FRANKFORD ARSENAL, PA., *August* 26, 1879.

Respectfully returned to the Chief of Ordnance, U. S. A.

The sample multiball cartridge for caliber ″.45 Colt's revolver strikes me as the best that can be done for service revolver with choke in chamber to prevent bullets advancing. The corresponding choke in shell reduces diameter of bullet ″.02 double thickness of wall of shell. This prevents slugging for taking grooves of barrel to any extent. With the round bullet its importance diminishes, however. The sample is strong and the balls well protected. Twenty-five grains powder seems to be charge enough for a cartridge of this kind.

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, August 29, 1879.

Respectfully referred to the commanding officer of National Armory for trial and report, and to call upon commanding officer of the Frankford Arsenal for more cartridges if necessary.

S. C. LYFORD,
Acting Chief of Ordnance.

NATIONAL ARMORY, *October* 16, 1879.

Respectfully returned to the Chief of Ordnance with the report called for in the preceding indorsements.

J. G. BENTON,
Colonel of Ordnance, Commanding.

Proceedings of a board of officers convened in obedience to the following order:

[Post Orders No. 30.]

NATIONAL ARMORY, SPRINGFIELD, MASS., *October* 6, 1879.

* * * * * * *

Par. II.—A board of officers, to consist of First Lieut. Rogers Birnie, jr., Ordnance Department, and First Lieut. C. C. Morrison, Ordnance Department, will convene at this armory to-morrow, the 7th instant, at 10 o'clock a. m., or as soon thereafter as practicable, to test and report upon the Wright multiball cartridges for service revolvers.

By command of Col. J. G. Benton:

D. A. LYLES,
Lieutenant of Ordnance, Post Adjutant.

NATIONAL ARMORY,
Springfield, Mass., October 7, 1879.

The board met pursuant to the foregoing order.

Present, both the members.

The convening officers having submitted to the board the Wright multiball cartridge, adapted to Colt's service revolver, they proceeded to comparative tests of this cartridge and the service cartridge, firing each in turn, under the same circumstances, and by the same marksman.

The object of the trial was to obtain direct comparisons of the two cartridges as to—

1st. Initial and remaining velocities.

2d. The energy at different ranges.

3d. The recoil.

4th. The penetration.

5th. The accuracy in firing with muzzle-rest.

6th. The accuracy in firing, moving on horseback and on foot, at a front or body of men.

7th. The dispersion.

Arms and ammunition used, Colt's service revolver, caliber ″.45; Wright's multiball revolver cartridge, caliber ″.45; service revolver cartridge, caliber ″.45.

The multiball cartridge submitted to the board has a case similar to the service cartridge, excepting in its length, being 1″.61, and in its being bottled forward to pass the choke in the chamber. The mean of the charge of powder obtained from the cartridges is 25 grains. There are three bullets, each weighing 110 grains, and having a diameter of ″.428. The two extreme balls are segments of spheres, with one base, the radius of which is one-eighth of an inch; the middle ball is a segment of a sphere, the radii of whose bases are each one-eighth of an inch. The powder is closely compressed, so as to occupy but ″.42 of the case. Drawings of the cartridge are appended hereto, marked A.

VELOCITIES.

The following is a table of comparative velocities:

TABLE I.

Bullet.	Weight of powder.	Weight of bullets.	Initial velocities.	Remaining velocities.			
				25 yards.	50 yards.	75 yards.	100 yards.
	Grains.	*Grains.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Service................	28	230	725	709	695	681	667
Multiball..............	25	330	690	637	591.5	554	517.5

The initial velocity for the service bullet, 725 feet, is assumed as its mean average velocity.

The initial velocity for the multiball bullets, 690 feet, is deduced from a series of 33 measurements by the Boulenge's chronograph. List appended, marked B.

The multiball velocities will be found to vary between widely separated extremes, each ball of the three differing from the others. The middle ball was found to be second in penetration, hence in velocity. Up to 25 yards it was the most accurate. It is noticeable in the velocities recorded that it cut the second target the most often of the three, those velocities between 681 and 697 feet probably belonging to this ball. The uncertainty, however, as to the ball by which the wires were cut caused the board to take the mean velocity of the thirty-three as the mean velocity of all. This velocity is used in computing the mean energy of the three balls, the table of comparative energies being as follows:

TABLE II.

Bullet.	Weight of powder.	Weight of bullet.	25 yards.	50 yards.	75 yards.	100 yards.
	Grains.	*Grains.*	*Foot-pounds.*	*Foot-pounds.*	*Foot-pounds.*	*Foot-pounds.*
Service	28	230	256.8	246.7	236.9	227.3
Multiball	25	110	99.1	85.5	75	65.5

RECOILS.

The theoretical recoils are, respectively, for the service cartridges, 3.7 foot-pounds; for the multiball cartridges, 6.86 foot-pounds; deduced from the following data:

Weight of revolver, 16,784 grains.
Weight of service bullet, 230 grain.
Velocity of service bullet, 725 feet.
Weight of (3) multiball bullets, 330 grains.
Mean velocity of (3) multiball bullets, 690 feet.
Force of gravity, 32.16 feet.

Although the theoretical recoil is seen to be nearly twice as great as with the service cartridge, the shock was not found to be such as to tire the hand in firing fifty multiball cartridges in quick succession.

Assuming that the increased recoil has no effect on the accuracy of the fires, as has been shown in this case of the service-cartridge, it would be no material objection.

PENETRATION.

In determining the penetration, white-pine butts were used, made of inch boards, with 1″ spaces intervening between the layers of boards. Five complete targets were made at each of the ranges, 50, 75, and 100 yards, and eight complete targets at 25 yards, giving mean results found in the following table:

TABLE III.

Multiball bullets.	25 yards.	50 yards.	75 yards.	100 yards.
	Inches.	*Inches.*	*Inches.*	*Inches.*
1..	2.06	1.9	1.42	.98
2..	1.6	1.6	1.26	.74
3..	1.3	1.25	1.04	.44
Mean of 3 balls	1.65	1.58	1.24	.72

In determining the penetration at 25 yards, cartridges were used with the forward bullet marked by replacing about two grains of the lead by the same weight of vermilion, pressed into the hole from which the lead was taken, so as not to alter the shape of the ball. This enabled the board to determine which ball had the greatest penetration, hence the greatest initial velocity. The result proved the forward bullet to have the maximum penetration, the middle ball to be second, and the rear ball third.

Reasoning from analogy, at each of the other ranges the same would be true; hence the balls numbered 1, 2, and 3 are presumed to be the forward, middle, and rear balls, respectively. Tabulated records of the targets for penetration are appended, marked C.

The penetration of the service bullet at 50 yards is 3½ inches; at 100 yards, 3¼ inches.

ACCURACY WITH MUZZLE-REST.

For the purpose of direct comparison, targets of ten shots, fired with muzzle-rest at a 12′ butt, were made at 25, 50, 75, and 100 yards. (See Plates XXXV and XXXVI.) The results of which are expressed in the following table:

TABLE IV.

Cartridges.	No. of bullets.	25 yards. Mean absolute deviation.	25 yards. No. of hits.	50 yards. Mean absolute deviation.	50 yards. No. of hits.	75 yards. Mean absolute deviation.	75 yards. No. of hits.	100 yards. Mean absolute deviation.	100 yards. No. of hits.
		Inches.		*Inches.*		*Inches.*		*Inches.*	
Service	10	3.29	10	5.67	10	10.12	10	13.76	10
Multiball	30	4.09+	30	10.45	30	20.66	25	28.53	18

In obtaining the mean absolute deviation of the multiball, that ball which was nearest of the three to the point aimed at, viz, the center of the target, was taken, rather than the center of impact of the three, as giving the more nearly just comparison. It is seen for a single object aimed at above 25 yards the accuracy of the service-cartridge is about twice that of the multiball; but when the dispersion of the latter used against a front of men is considered, this apparent want of accuracy is compensated for.

The target record from which the mean absolute deviations were obtained is appended, marked D.

ACCURACY IN FIRING, MOVING.

To determine this, the service conditions were obtained as nearly as possible.

Sergeant Donovan, of the National Armory detachment, was selected as about equal, possibly a little superior, to the average shot, as marksman. The figures of ten men, rudely drawn on a canvas rectangle 18′ 6″ by 6′ feet, were taken as a target. This target was approached perpendicularly to its front at an easy gallop. Firing was

commenced at 100 yards with the multiball cartridge. Six shots were delivered between 100 and 60 yards. The same was then done with the service-cartridge. The target was then approached in the same manner, six shots being fired between 60 and 25 yards; then between 40 and 10 yards. In each series of six shots the service alternating with the multiball.

The same was done on foot at a run, checking the speed, but not halting, to fire; the distances between which the six shots were delivered being as given in the following table.

The target was then fired at on foot, running, while passing it parallel to its front, at a distance of 30 yards from it; firing commencing and ending about 50 yards obliquely distant from its center.

The ground over which the target was approached on horseback and on foot was rough, in places slippery.

The following tables exhibit the results, and copies of the targets are appended (Plates XXXVII, XXXVIII, and XXXIX), giving in each case the results of the most successful trials:

TABLE V.

(Fired on horseback at a gallop.)

Cartridge.	From 100 to 60 yards.			From 60 to 25 yards.			From 40 to 10 yards.		
	No. of trial.	Shots fired.	Hits.	No. of trial.	Shots fired.	Hits.	No. of trial.	Shots fired.	Hits.
Service	1st	6	1	1st	6	2	1st	6	3
	2d	6	1	2d	6	3	2d	6	2
	.....	.....	.....	3d	6	2	3d	6	4
	.....	.....	.....	4th	6	3	.....	.....	.....
Total	2	12	2	4	24	10	3	18	9
Multiball	1st	6	5	1st	6	11	1st	6	7
	2d	6	2	2d	6	9	2d	6	3
	.....	.....	.....	3d	6	5	3d	6	6
	.....	.....	.....	4th	6	3	.....	.....	.....
	2	12	7	4	24	28	3	18	16

TABLE VI.

(Fired on foot at a run.)

Cartridge.	From 100 to 65 yards.		From 75 to 45 yards.		From 50 to 25 yards.		From 35 to 17 yards.	
	No. of shots.	Hits.	No. of shots.	Hits.	No. of shots.	Hits.	No. of shots.	Hits.
Service	6	2	6	2	6	5	6	6
Multiball	6	11	6	7	6	10	6	16

TABLE VII.

(Fired on foot at a run.)

Cartridge.	First trial.		Second trial.	
	No. of shots.	Hits.	No. of shots.	Hits.
Service	6	3	6	1
Multiball	6	6	6	7

From the foregoing tables it will be seen that in 54 shots fired from on horseback, moving at gallop, at distances varying between 100 yards and 10 yards, 21 service-bullets hit the target, and in the same number of shots, similarly fired, of multiball cartridges, 51 bullets struck the target; that of 24 shots fired running, on foot, between 100 yards and 17 yards, 15 service and 44 multiball bullets struck the target; that of 12 shots fired while running on foot parallel to it, 4 service and 13 multiball bullets hit the target.

The average time of firing the six multiball cartridges was 10¾ seconds; that for the six service-bullets, 12¼ seconds.

DISPERSION.

Examining Plates XXXV and XXXVI, it will be seen that the average circumscribing rectangle at 25 yards of the groups of shots in the multiball is 16″ by 16½″, making it possible to hit two files at 50 yards; the average rectangle being 40⅝″ by 30⅝″, two files, possibly three, may be hit. Between 75 and 100 yards the spread covers more than three files, rendering it possible to hit three men in a front.

CONCLUSIONS.

The efficiency of the cartridge turns upon two considerations: first, accuracy; second, effective energy.

In point of accuracy, when used either against a single file or a front or body of men, under the usual service conditions, viz, without rest, and fired by pointing, not sighting, the multiball cartridge is a little superior to the service up to 25 yards; between that and 50 yards, nearly twice that of the service against a front of men, and nearly equal to the service against a single file.

Between 50 and 100 yards it approaches nearly three times that of the service-cartridge against a front of men.

The board finds the question of effectiveness a very serious one about which to arrive at a conclusion, with available data. Even at 50 yards, which they consider a minimum effective range for a revolver-cartridge, the energy of one of the three bullets is scarcely more than one-third of that of the service-bullet at the same range.

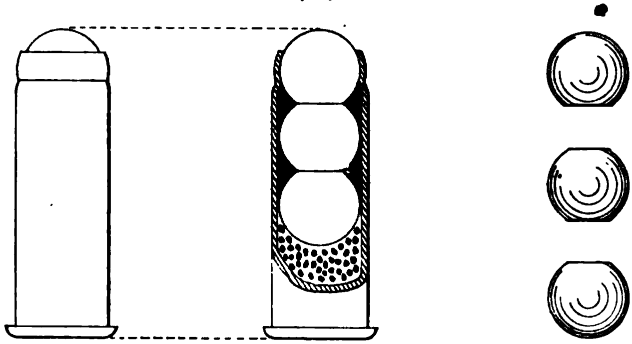
The experiments lead to the conclusion of a probable and marked superiority (on account of the greater number of balls) of the multiball cartridge over the service, to include a range of 50 yards; but even within this limit, it is believed a well-grounded conclusion can only be

arrived at by actual trial in service, in order to determine the capability of the multiball bullet to inflict a dangerous or a fatal wound.

Independent of other considerations, if it be intended to have this multiball cartridge succeed the present uniball, it seems to the board that a great sacrifice of weight and diameter of ball is made in utilizing a .45″-caliber rifled revolver for firing a .428″ spherical bullet, to gain the adaptation of the cartridge to the present choke of the chamber, a much heavier ball being in their opinion at least desirable. The cartridge submitted cannot be fired from the Smith and Wesson revolvers now in the hands of troops.

R. BIRNIE, JR.,
Lieutenant of Ordnance, President.
CHARLES C. MORRISON,
Lieutenant of Ordnance, Recorder.

(A.)



(B.)

Initial velocity of Wright's multiball cartridge; from a series of 33 measurements by the Boulengé chronograph.

Number.	Feet.	Number.	Feet.	Number.	Feet.
1	718	12	666	23	692
2	718	13	682	24	687
3	693	14	694	25	709
4	672	15	681	26	681
5	681	16	665	27	671
6	711	17	714	28	686
7	662	18	695	29	689
8	707	19	689	30	708
9	694	20	673	31	683
10	714	21	713	32	697
11	710	22	686	33	659
Mean					690

(C.)

Penetration in white pine.

Number of shot.	Number of ball.	Penetration at 50 yards.	Penetration at 75 yards.	Penetration at 100 yards.
		Inches.	*Inches.*	*Inches.*
1	1	1.9	1.5	1.2
	2	1.8	1.2	.9
	3	1.2	1.0	.3
2	1	1.9	1.5	.9
	2	1.6	1.3	.8
	3	1.4	1.1	.5
3	1	1.9	1.3	.8
	2	1.6	1.2	.5
	3	1.3	1.0	.4
4	1	2.0	1.4	.9
	2	1.5	1.2	.9
	3	1.1	1.0	.6
5	1	1.8	1.4	1.1
	2	1.0	1.4	.6
	3	1.3	1.1	.4

AT 25 YARDS.—*Penetration in white pine.*

Number of shot.	Forward ball, penetration.	Middle ball, penetration.	Rear ball, penetration.
	Inches.	*Inches.*	*Inches.*
1	2.0	1.5	1.2
2	2.0	1.5	1.3
3	2.5	1.5	1.0
4	2.2	1.7	1.3
5	2.0	1.6	1.2
6	1.8	1.6	1.4
7	2.1	1.5	1.0
8	1.9	1.8	1.7

At 25 yards the front balls were marked so the three could be distinguished after firing. The forward ball was found to have the greatest penetration, the middle second, rear third. The average distance of the several balls from the point aimed at was, forward ball, 8.2 inches; middle ball, 6.6 inches; rear ball, 9.9 inches; showing the middle ball at this range to have the greatest accuracy.

(D.)

Target record for accuracy, using in each case that bullet of the multiball charge which carried nearest the center of the target for comparison with the (single) service bullet.

RANGE, 25 YARDS.

Number of shot.	THE MULTIBALL BULLET.								THE SERVICE BULLET.							
	Distances expressed in inches.															
	From center of target.				From center of impact.				From center of target.				From center of impact.			
	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
1	....	4	2.5	......	—	7.5	4.2	......	....	3.5	4	......	......	1.5	5.0	....
2	2	....	4	......	......	1.5	5.7	......	....	3	—	—	......	1.0	1.0	....
3	5	....	......	3	1.5	....	......	1.3	....	1.5	....	1.5	.5	......	......	.5
4	7	....	......	5	3.5	....	......	3.3	2	......	....	1	4.0	[illegible]	—	—
5	5	....	......	7	1.5	....	......	5.3	...	4	....	2.5	......	2.0	......	1.5
6	6	....	......	2	2.5	....	......	.3	....	1	....	3.5	1.0	......	......	2.5
7	6	....	......	5	2.5	....	......	3.3	....	.5	....	4.5	1.5	......	......	3.5
8	4	....	......	3.5	.5	....	......	1.8	....	2.5	3.5	......	......	.5	4.5	....
9	...	.5	......	2	......	4	......	.3	—	—	2	......	2.0	......	3.0	....
10	5	....	4	......	1.5	....	5.7	......	....	6	....	7	......	4.0	......	6.0
	3.5	....	......	1.7	M. A. deviation, 4.09+				....	2.0	....	1.0+	M. A. deviation, 3.29—			
	Center of impact.								Center of impact.							

RANGE, 50 YARDS.

Number of shot.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
1	....	1	......	5	......	2.8	.6	......	.5	......	3.5	......	8.4	......	6.3	....
2	6	....	1.5	......	4.2	....	7.1	......	....	7	7	......	.9	......	9.8	....
3	9	....	9	......	7.2	....	14.6	......	....	11	2	......	......	3.1	4.8	....
4	—	—	10	......	......	1.8	15.6	......	....	10	....	1	......	2.1	1.8	....
5	....	5	......	3.5	......	6.8	2.1	......	....	4	....	8	3.9	......	......	5.2
6	....	1	......	25	......	2.8	......	19.4	....	5	....	5.5	2.9	......	......	2.7
7	6	....	......	7.5	4.2	....	......	1.9	....	7	....	9.5	.9	......	......	6.7
8	5	....	......	4	3.2	....	1.6	......	....	11	....	4.5	......	3.1	......	1.7
9	....	8	......	1	......	9.8	4.6	......	....	11.5	....	7	......	3.6	......	4.2
10	7	....	......	31	5.2	....	......	25.4	....	13	....	5	......	5.1	......	2.2
	1.8	....	......	5.6	M. A. deviation, 10.45				....	7.9	....	2.8	M. A. deviation, 5.67			
	Center of impact.								Center of impact.							

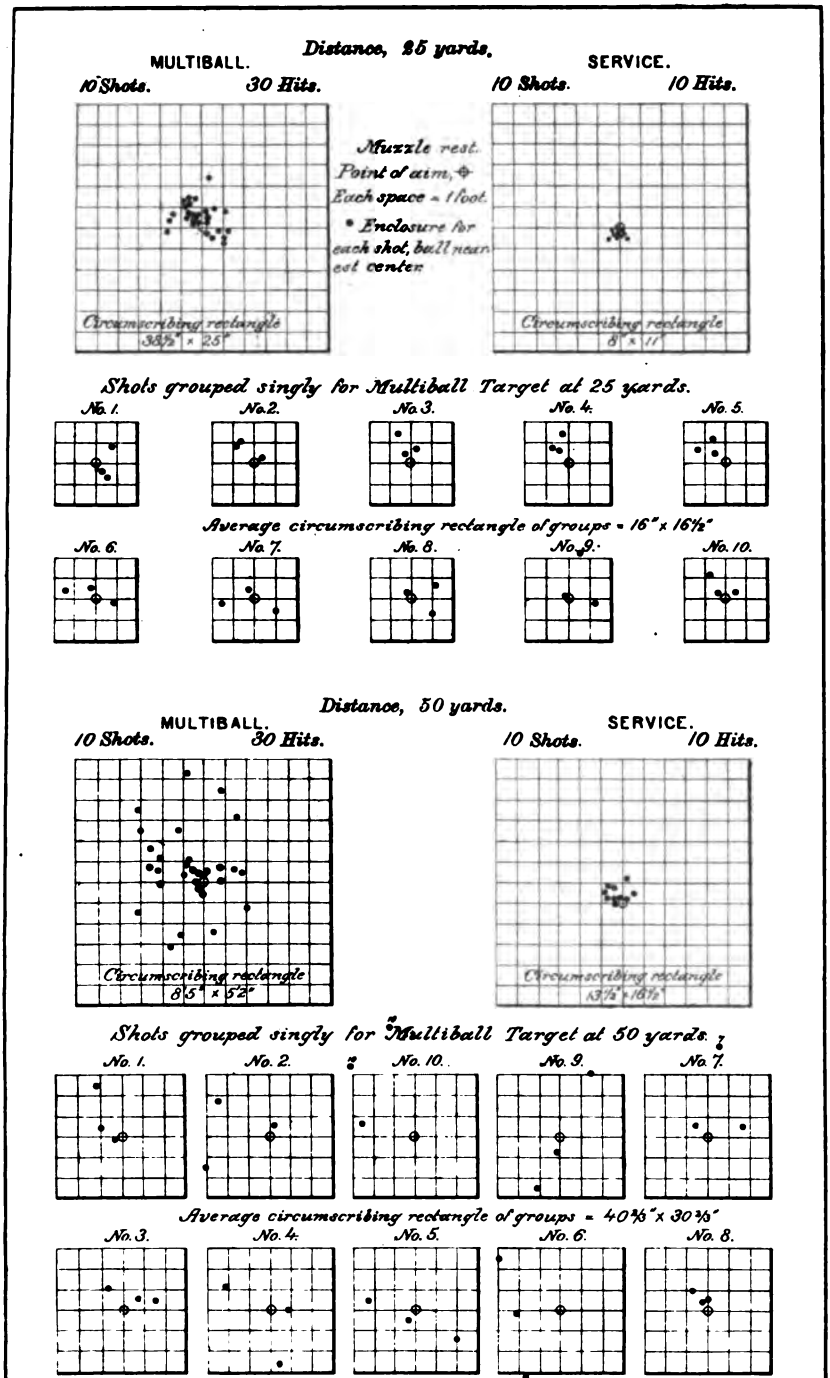
(D)—Continued.

RANGE, 75 YARDS.

Number of shot.	THE MULTIBALL BULLET.								THE SERVICE BULLET.							
	Distances expressed in inches.															
	From center of target.				From center of impact.				From center of target.				From center of impact.			
	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
1..	......	41	9	......	......	36.6	13.6	......	14	......	.....	2	22.7	......	7	....
2..	5.5	......	......	16	9.9	......	......	11.4	4.5	......	.....	5	13.2	......	4	....
3..	......	40	5.5	......	......	35.6	10.1	......	.....	3	.....	12	5.7	......	......	3
4..	15	......	4.5	......	19.4	......	9.1	......	.....	5	—	—	3.7	......	9	....
5..	......	10	5.5	......	......	5.6	10.1	......	.....	11	.....	8	......	2.3	1	....
6..	......	4	20	......	.4	......	24.6	......	.....	10	.....	15	......	1.3	......	6
7..	.5	......	......	4	4.9	......	.6	......	.....	15.5	.....	7.5	......	6.8	1.5	....
8..	15	......	......	37.5	19.4	......	......	32.9	.....	16	.....	16	......	7.3	......	7
9..	......	5	......	5	......	.6	......	.4	.....	22.5	.....	11	......	13.8	......	2
10..	20	......	......	28.5	......	......	......	23.9	.....	22.5	.....	13.5	......	13.8	......	4.5
	......	4.4	......	4.6+	M. A. deviation, 20.66.				.....	8.7	.....	9.0	M. A. deviation, 10.12.			
	Center of impact.								Center of impact.							

RANGE, 100 YARDS.

Number of shot.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.	A.	B.	R.	L.
1..	......	10	......	16	11.6	......	14.7	......	.....	2	.....	11	22.20	......	—	—
2..	......	2.5	......	19.5	19.1	......	11.2	.....	....	12	.....	11	12.2	......	—	—
3..	......	31	......	49.5	......	9.4	......	18.8	.....	10.5	.....	17	13.7	......	......	6.0
4..	......	29	......	19	......	7.4	11.7	......	.....	19	10	......	5.2	......	21.0	....
5..	......	44	4	......	......	22.4	34.7	......	....	20	.....	7.5	4.2	......	3.5	....
6..	......	41	......	51	......	19.4	......	20.3	.....	31	.....	18.5	......	6.8	......	7.5
7..	......	51	......	69	......	29.4	......	38.3	.....	38	.....	11.5	.....	13.8	......	.5
8..	......	11.5	......	2.5	10.1	......	28.2	.....	.....	37	.....	7	......	12.8	4.0	....
9..	......	7	......	46	14.6	......	......	15.3	.....	50	.....	4.5	......	25.8	6.5	....
10..	10.5	......	......	39	32.1	......	......	8.3	.....	22.5	.....	32	1.7	......	......	21.0
	......	21.6+	......	30.7+	M. A. deviation, 28.53.				.....	24.2	.....	11.0	M. A. deviation, 13.76.			
	Center of impact.								Center of impact.							

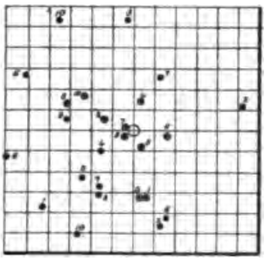


Appendix W.—Report of the Chief of Ordnance, 1879.

Distance 75 yards.

MULTIBALL.

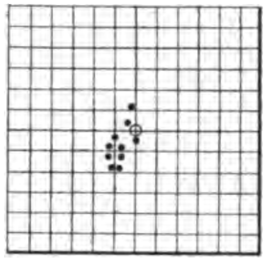
10 Shots. *25 Hits.*



Average circumscribing rectangle of 6 complete groups = 82."2 x 56."5

SERVICE.

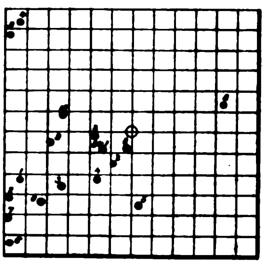
10 Shots *10 Hits.*



Distance, 100 yards.

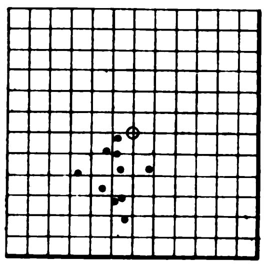
MULTIBALL.

10 Shots. *18 Hits.*



SERVICE.

10 Shots. *10 Hits.*



Muzzle rest.
Point of aim ⊕
Each space = 1 foot.
• *Enclosure for each shot; ball nearest center.*

18 Shots fired at each target, from the saddle with horse approaching at gallop.

Target 18½ × 6 Feet.

23 hits out of 54 bullets, Multiball cartridges;

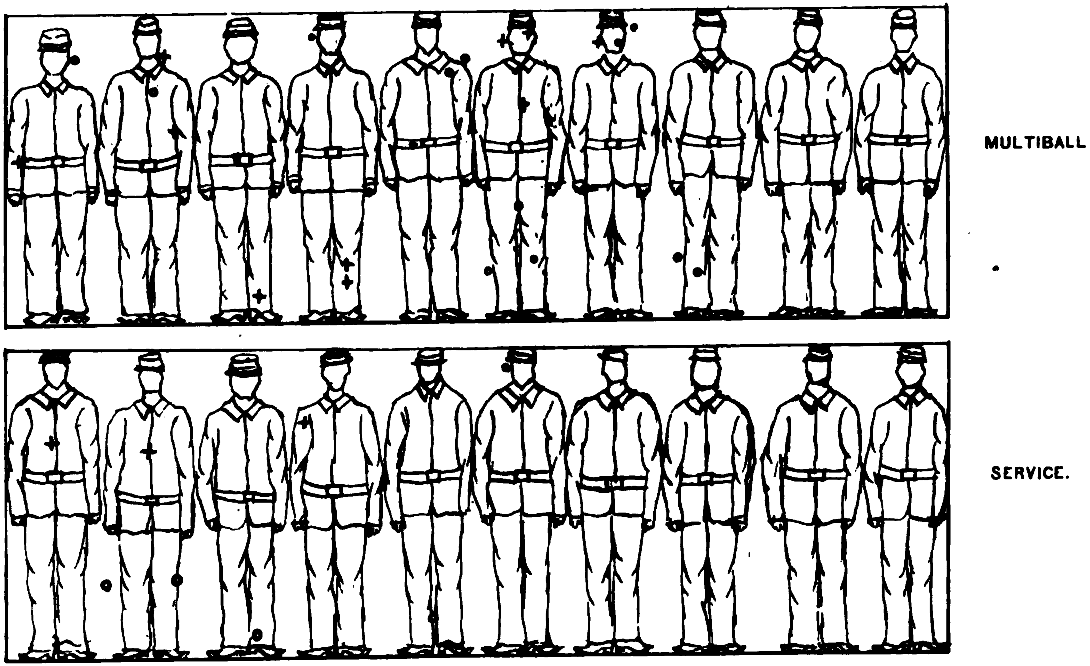
8 hits out of 18 bullets, Service cartridges.

Shots fired between

100 and 60 yds. ●

60 and 25 yds. +

40 and 10 yds. ○

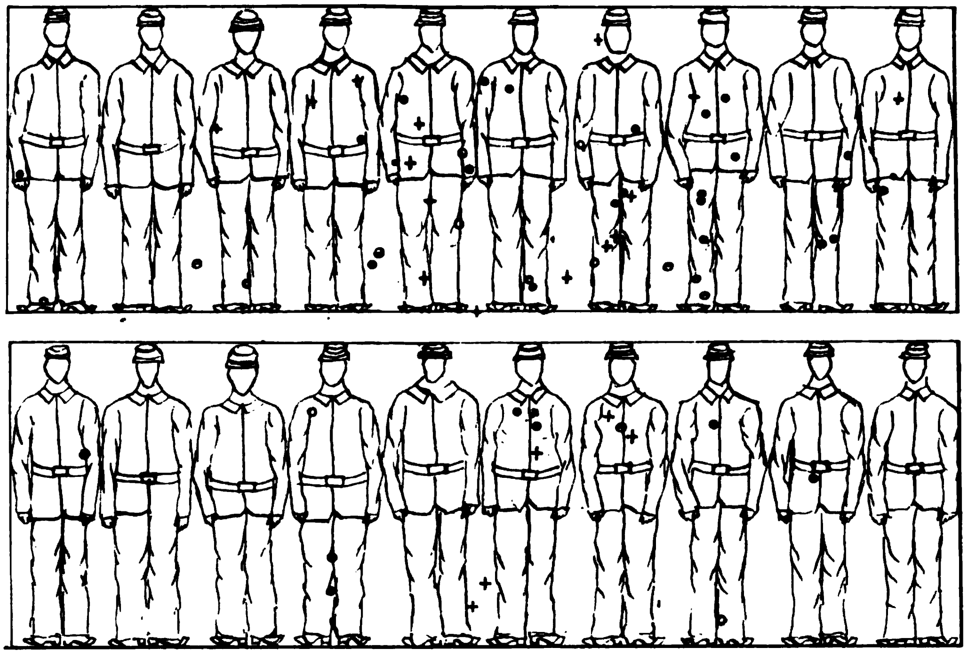


24 Shots approaching target running on foot from 100 to 17 yards.

Target 18½ x 6 Feet.

49 hits out of 72 bullets, 24 multiball cartridges; 15 hits out of 24 bullets, service cartridges.

Shots fired between
100 and 65 yds. ●
75 and 45 yds ○
50 and 25 yds +
35 and 17 yds. ●

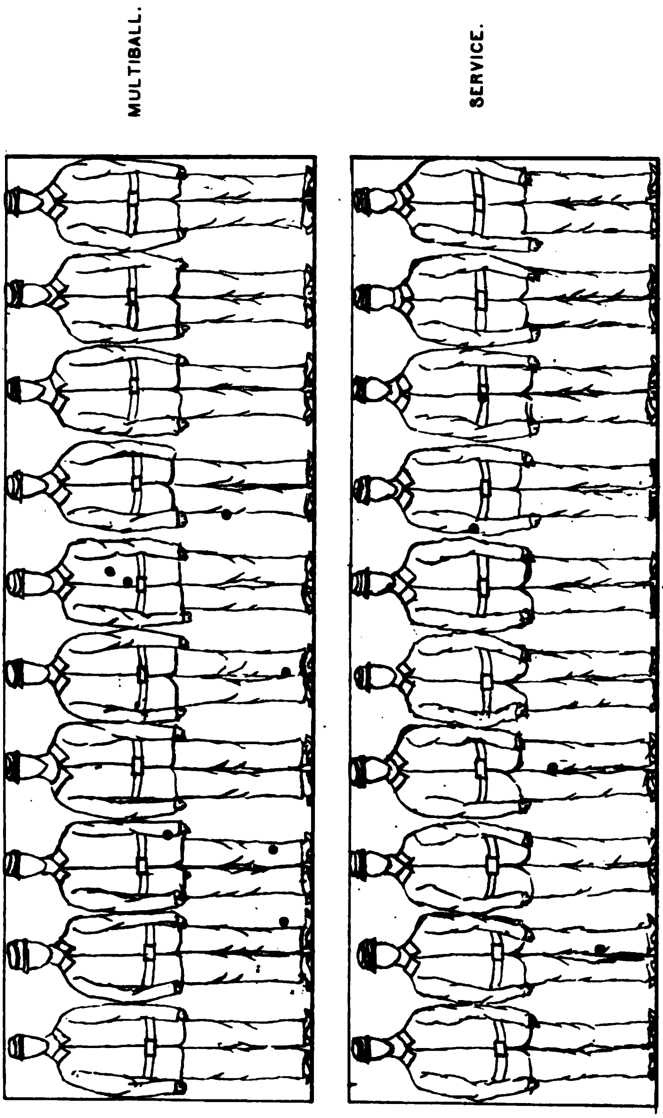


MULTIBALL.

SERVICE.

6 Shots fired whilst running on line parallel and 30 yards from target, on foot; commencing obliquely about 50 yards from target.

7 hits out of 18 bullets, multiball cartridges; 3 hits out of 6 bullets, 6 service cartridges.



(One plate.)

FIRST REPORT ON MERWIN, HULBERT & CO.'S MULTIBALL CARTRIDGES MADE BY MAJ. J. M. WHITTEMORE AT FRANKFORD ARSENAL, 1879.

FRANKFORD ARSENAL, *April* 23, 1879.

SIR: In compliance with your instructions of 7th and 15th instants, I have the honor to submit the following report on multiball cartridges submitted for trial by Merwin, Hulbert & Co., of New York City:

In the annexed sketch Plate XL, figures 1, 2, and 3 represent the rifle cartridges, and figure 4 the revolver cartridge. Another cartridge, not shown in sketch, was also tried, and will be referred to as No. 5.

The programme of the experiments was suggested by Mr. Moore, the representative of Merwin, Hulbert & Co.

DESCRIPTION OF CARTRIDGES.

No. 1 contains 3 round balls, diameter 0''.425; weight, 110 grains.

No. 2 contains 2 round balls and 1 conical ball; weight, 112 grains.

No. 3 contains 3 spherical zones and 1 conical ball; weight, 112 grains.

No. 4 contains 2 spherical zones and 1 conical ball, same size and weight as No. 3.

No. 5 contains 4 round balls, same size and weight as No. 1.

Nos. 1, 2, and 3 contained 68 grains powder; No. 4, 29 grains powder, and No. 5, 50 grains powder.

The balls in all were inclosed in a stout paper case saturated with a mixture of paraffine and beeswax. The paper case of some were varnished with shellac with a view of preventing evaporation of the lubricant under high temperatures. The balls so inclosed are inserted in the ordinary metallic cartridge case over a charge of powder and the case crimped, leaving the front ball projecting from its mouth from 0''.5 to 0''.6, and, therefore, the front ball is held in position by the paper envelope only.

ACCURACY AT 60 YARDS.

No. 1, mean absolute deviation	1'.007
No. 2, mean absolute deviation	2'.833
No. 3, mean absolute deviation (16 misses)	1'.702
No. 5, mean absolute deviation	3'.520

ACCURACY AT 100 YARDS.

No. 1, mean absolute deviation (3 misses)	2'.440
No. 2, mean absolute deviation (7 misses)	2'.937
No. 3, mean absolute deviation (16 misses)	1'.389
No. 5, mean absolute deviation	2'.796

FOULING.

No. 1 *cartridge,* 100 *rounds fired, barrel weighed after each* 20 *shots but not cleaned.*

After 20 shots; fouling, 6 grains.
After 40 shots; fouling, 6 grains.
After 60 shots; fouling, 11 grains.
After 80 shots; fouling, 12 grains.
After 100 shots; fouling, 10 grains.

APPROXIMATE EFFECTIVE RANGES.

No. 5, at 100 yards, 12 hits, 6 misses.
No. 1, at 150 yards, 11 hits, 7 misses.
No. 2, at 150 yards, 8 hits, 10 misses.

No. 3, at 150 yards, 6 hits, 18 misses.
No. 5, at 150 yards, 9 hits, 9 misses.
No. 1, at 200 yards, 9 hits, 9 misses.
No. 2, at 200 yards, 2 hits, 16 misses.
No. 3, at 200 yards, 2 hits, 22 misses.

The preceding results are for rifle ammunition.

REVOLVER AMMUNITION (No. 4).

Accuracy (fixed rest).

Mean absolute deviation, 15 yards	0'.394
Mean absolute deviation, 20 yards	0'.571
Mean absolute deviation, 30 yards	1'.773
Mean absolute deviation, 40 yards	1'.349
Mean absolute deviation, 40 yards	1'.735
Mean absolute deviation, 50 yards	1'.850
Mean absolute deviation, 60 yards	2'.048
Mean absolute deviation, 75 yards	3'.775

OFF-HAND FIRING.

Mean absolute deviation, 35 yards	1'.913
Mean absolute deviation, 35 yards	1'.993
Mean absolute deviation, 35 yards	2'.442
Mean absolute deviation, 35 yards	1'.890

No misses. Target 12 feet square. Point sighted 3' above center from 40 to 75 yards. Some of the rifle-cartridge balls struck the ground at 75 yards from the gun and others ricochetted, and afterward struck the target. Specimens picked up at the target showed that the spherical zones tumbled in flight.

This multiball ammunition possesses no advantage for military purposes over that already experimented upon at this arsenal by Capt. E. M. Wright, Ordnance Department.

It depends for sluggage upon the paper in which the bullets are inclosed; Captain Wright's upon the sluggage of the bullet itself, due to its increased diameter over that of the bore of the gun, which makes each spherical bullet weigh more than a corresponding one of this ammunition. It gives no better targets nor less fouling in 100 rounds.

The multiball ammunition made here, with lubricant, between the balls, and the shell crimped slightly over the front bullet to make the cartridge practically water-proof and keep powder, lubricant, and balls in their proper places, will, in my opinion, answer all the requirements of service for rifle and carbine ammunition better than this.

For revolvers, the paper envelope projecting beyond the mouth of the shell and holding the front projectile entirely, the ammunition presented has the advantage of giving a maximum powder space for length of shell and number of balls carried in and with it, which may be desirable for trade purposes.

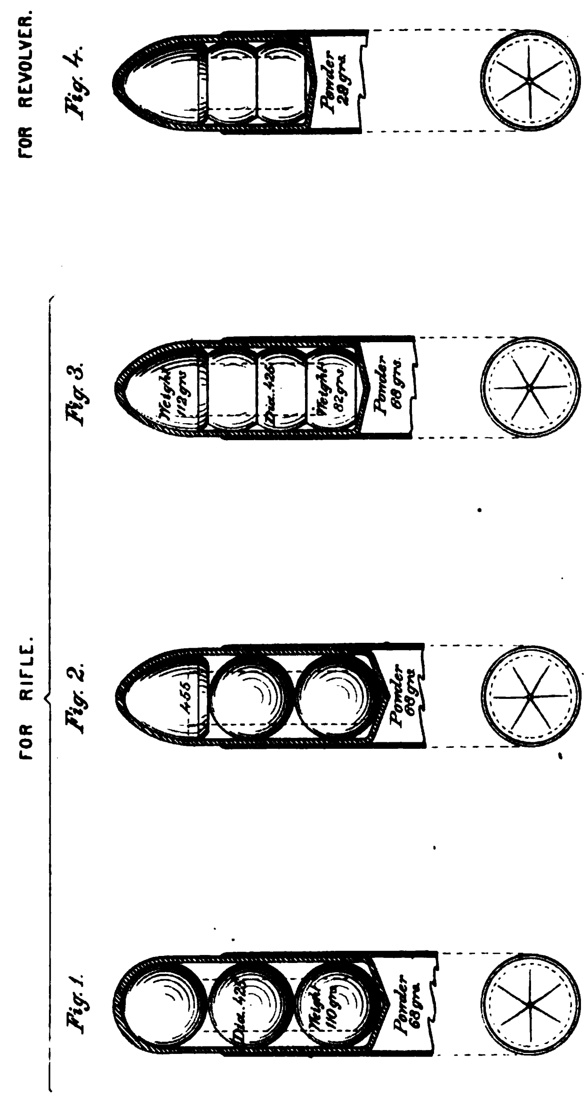
All these cartridges will stand transportation in quantity packed in boxes, but the front bullet projecting from the shell is not sufficiently secure in its paper envelope to stand the shocks it would be subjected to in the field and on the march if carried loosely in pouches or the loops of prairie-belts.

Very respectfully, your obedient servant,

JAS. M. WHITTEMORE,
Major of Ordnance, Commanding.

THE CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

MERWIN, HULBERT & CO'S MULTIBALL CARTRIDGES.



NEW YORK, *May* 12, 1879.

DEAR SIR: We duly received the report made by Major Whittemore upon our multiball cartridge, but we find that, from some inadvertence of ours or others, all the previous *experimental* tests have been embodied into this report. We would now ask you to grant us an official trial of our multiball cartridge, with one style of loading, and also that this cartridge has been made to meet the view of the Board as to the strength, for military purposes.

We are, with respect, yours very truly,

MERWIN, HULBERT & CO.

Gen. S. V. BENÉT,
Chief of Ordnance.

[Indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, May 13, 1879.

Respectfully referred to the commanding officer of National Armory, with the report on this cartridge made from the Frankford Arsenal, and with directions to test the cartridge if presented by the parties interested.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

NATIONAL ARMORY, *June* 27, 1879.

Respectfully returned to the Chief of Ordnance with a report herewith inclosed of the test called for by the preceding indorsement.

J. G. BENTON,
Lieutenant-Colonel, Commanding.

Proceedings of a Board of Officers convened at the National Armory, Springfield, Mass., pursuant to the following order, viz:

[Post Orders No. 12—Series of 1879.]

BOARD TO TEST MULTIBALL CARTRIDGES.

NATIONAL ARMORY,
Springfield, Mass., May 21, 1879.

A board to consist of Capt. J. E. Greer, Ordnance Department, and First Lieutenant Rogers Birnie, jr., Ordnance Department, will convene at this armory on Friday, the 23d instant, at 10 o'clock a. m., or as soon thereafter as practicable, to test and report upon the multiball cartridges submitted by Messrs. Merwin, Hulbert & Co., of New York City, N. Y.

By command of Lieutenant-Colonel J. G. Benton.

D. A. LY I
Lieutenant of Ordnance, Post A

Official:
D. A. LYLE,
Lieutenant of Ordnance, Post Adjutant.

NATIONAL ARMORY,
Springfield, Mass., May 27, 1879.

Ten o'clock a. m., the board met pursuant to the foregoing order.

Present: Both the members.

Mr. Moore, representing the firm of Merwin, Hulbert & Co., whose place of business is at 83 Chambers street, New York City, N. Y., presented to the board samples of their multiball cartridges.

Having determined upon a series of tests for the cartridges, the board resolved to meet as might be necessary to conduct the same, and at the conclusion thereof to meet for discussion and report.

NATIONAL ARMORY,
Springfield, Mass., June 23, 1879.

The Board has the honor to submit the following report:

The cartridges presented for trial were, viz, multiball cartridges for the service rifle, and multiball cartridges for the service revolver, in quantity sufficient to conduct the experiments herewith, accompanied at the hands of the agent of the firm by a list of advantages claimed for the cartridge, which list (in eleven paragraphs) is herewith, marked A.

The agent of the firm was present during the trials.

Descriptions of the cartridges, with drawings of the same, are herewith appended and marked B.

In the experiments conducted, after good workmanship and perfection of the cartridges, the Board had in view to determine their effectiveness in regard to accuracy, dispersion, penetration, and the limits of the ranges at which they might be equal to, superior, and inferior to, the present uniball cartridges. (See Addenda D.)

Plate XLII shows the complete targets made by firing (10) ten shots with the multiball (3-ball) cartridges from the rifle and carbine, each at ranges of 50, 100, 150, and 200 yards.

Plate XLIII shows every complete set of three hits made, in the above firings (by a single cartridge), plotted independently to show (individual) dispersion (as though the different shots had been fired at different portions of the target).

Plate XLIV shows corresponding targets for the revolver at ranges of 25, 50, and 75 yards.

Table of accuracy. (See Plates XLII and XLIII.) Ten (10) shots, (30) bullets, fired at target, 12′ square, with muzzle-rest, at ranges above 50 yards for rifle and 25 for revolver.

Arm.	Range.	Number of misses.	Number of hits.	Mean absolute deviation.	Remarks.
	Yards.			*Inches.*	
Rifle	50	0	30	14.8	
Carbine	50	1	29	18.3	Rifle cartridge.
Rifle	100	8	22	30.6	Do.
Carbine	100	8	22	25.4	Do.
Rifle	150	12	18	36.5	Do.
Carbine	150	12	18	31.3	Do.
Rifle	200	21	9	54.0	Do.
Carbine	200	18	12	46.4	Do.
Revolver	25	0	30	6.5	Revolver cartridge.
Revolver	50	4	26	25.4	Do.
Revolver	75	4	26	28.2	Do.

The mean absolute deviation of the service rifle-bullet at 200 yards (the extreme range here used), as found by actual experiments at this armory, is 2.″8, and of the service pistol-bullet at 75 yards (the extreme range here used), 5.″04; results with which the multiball cartridges, even at the shortest ranges used, do not compare. Moreover, the mean absolute deviation of the multiball cartridges is here shown to be less than it really is at the longer ranges, since only the hits can be used in computing; consideration of the misses would, of course, increase the deviation.

It must be remembered, however, that an essential of the multiball cartridge is to combine a proper *dispersion* with accuracy, and hence the unfavorable showing of the above method of comparison is not so apparent.

The following is deduced from a consideration of the groups (alone) of a single shot, and without reference to the point aimed at.

Table of dispersion with accuracy.

Range, yards.	Mean average spread.						Remarks.
	Rifle.		Carbine.		Revolver.		
	Horizontally.	Vertically.	Horizontally.	Vertically.	Horizontally.	Vertically.	
	″	″	″	″	″	″	
25	......	......	......	......	10.2	10.3	Average of 10 complete sets of three.
50	25.4	16.5	33.7	18	38.6	29.8	R. Average of 10 complete sets of three. C. Average of 9 complete sets of three. P. Average of 6 complete sets of three.
75	......	......	......	......	56.6	36.2	Average of 6 complete sets of three.
100	75.7	14.5	39.25	40.25	......	......	R. Average of 4 complete sets of three. C. Average of 4 complete sets of three.
150	90.7	61	19	21	......	......	R. Average of 3 complete sets of three. C. One set only.
200	—	—	71	73	......	......	R. No complete sets. C. One set only.

NOTE.—See Plates XLIII and XLIV.

Which shows for the revolver that at 25 yards the three balls will fall within the area of a single file (soldier), at 50 yards the spread covers two men, and at 75 yards reaches three men.

For the rifle and carbine at 50 yards the spread covers two men; at 100 yards four men for the rifle, and the carbine two and over; and at 150 yards the (rifle) balls may reach a front of five men. In none of these cases does the vertical spread exceed the height of a man.

The number of complete sets at the higher ranges being limited, the following is deduced by a simple inspection of the targets, Plates XLII and XLIII (showing result for ten multiball cartridges).

Range, yards.	Number of shots that would strike a single file.		Number of shots that would strike a front of men equal to width of target.	
	Rifle.	Carbine.	Rifle.	Carbine.
100	3	7	18	20
150	3	2	13	15
200	0	1	3	8

Taking from this an average of the rifle and carbine, we find that in firing at a single file it takes at 100 yards two shots to hit, at 150 yards four shots to hit; but with a front of men we have from the 10 shots a greater number of balls than 10 single-bullet cartridges would give.

At 200 yards the inferiority of the multiball, both for hitting a single object and a front of men, is apparent.

As regards * *hitting effect*, the conclusion then is:

For the revolver cartridge.

Up to 25 yards (and probably 30) it is not superior to the uniball (since the three balls group within so small an area).

Above that range the effect is equal to two, and sometimes three, uniball cartridges.

For the rifle cartridge.

Upon to 30 yards (about) it is not superior to the uniball (the grouping is so small.)

Between 30 and 175 yards (about) in firing at a front of men the (hitting) effect may be equal to three uniball cartridges.

In firing at a single object it is inferior to the uniball above 100 yards.

* "Hitting effect" here used simply to indicate "probability (or chances) of hitting."

Table of penetration.

Range, yards.	Mean penetration in pine.				Remarks.
	Rifle.	Carbine.	Revolver.		
			Ogival balls.	Segments.	
	″	″	″	″	
25	....	....	1.75	1.29	O. Mean of 3 hits. S. Mean of 6 hits.
50	3.48	3.25	1.75	1.05	R. Mean of 12 hits. C. Mean of 10 hits. P. O. Mean of 2 hits. P. S. Mean of 5 hits.
75	....	....	1.06	0.625	O. Mean of 4 hits. S. Mean of 6 hits.
100	2.35	2.29	....	....	R. Mean of 7 hits. C. Mean of 6 hits.
150	1.60	1.57	....	....	R. Mean of 5 hits. C. Mean of 7 hits.
200	1.225	1.25	....	....	R. Mean of 2 hits. C. One hit only.

In the revolver cartridges the difference between the penetration of the ogival and segments was quite apparent; a record of this firing is appended and marked C.

Attention has heretofore been called to the light concussion balls of this kind would give (Captain Greer's report on the Wright multiball cartridge), and that an inch of penetration would by no means give a wound equal to one made by a heavy bullet having the same penetration.

Assuming that 1″.5 penetration with these balls would inflict a dangerous wound, we see that the effective range of the rifle-bullet multiball is limited to 160 yards (about); and with the pistol, even at 25 yards, but one of the bullets in the cartridge has a penetration of 1″.5.

The fouling was found to be very slight. After 70 rounds had been fired from the rifle and carbine each, the barrels were carefully weighed, then cleaned and re-weighed; the rifle gave 5 grains fouling, the carbine no perceptible fouling.

The recoil was found to be not excessive.

The diversity of the spread at different ranges in regard to directions, vertical and horizontal, shows that the casing of the balls takes the grooves of the rifling; the case seemed to rupture uniformly and fall near the muzzle of the piece, only in exceptional cases parts of it reaching the target with the ball.

The cartridges are firmly constructed; the metallic case partly incloses and clamps the forward balls, and the Board assents generally to the claims set forth by the inventors, so far as the tests applied show, with such exceptions and conditions as are herein set forth.

The question naturally arises whether it would be advisable to encumber men in action with cartridges which, in the opinion of the Board, as revolver cartridges, are not at any range superior to the uniball to inflict a dangerous wound, and in any case could not be used with effect beyond 75 yards, and as rifle cartridges could not be used with effect beyond 175 yards, while their superiority to the uniball is limited between 30 and 160 yards.

JOHN E. GREER,
Captain of Ordnance, United States Army, President of the Board.

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Recorder.

(A.)

Advantages claimed for encased multiball metallic cartridge of Merwin, Hulbert & Co.

First. No leading of barrel by any number of discharges.

Second. At each discharge the casing acts as a cleaner and lubricates the barrel.

Third. The lubricated case taking the rifling gives an easy transit of balls and accuracy of flight.

Fourth. The lubricant is preserved under the different ordinary degrees of temperature.

Fifth. By the centrifugal force given to the casing and balls by the rifling, the casing is thrown off after leaving the barrel, the balls diverge or separate nearly equal to the front of three men at about one hundred yards distance.

Sixth. This multi (3-ball) cartridge in its effective (or destructive) results at each discharge at short range is nearly equal to three separate discharges by a breech-loader throwing one ball.

Seventh. The cartridge is firmly constructed and will withstand rough usage of actual service and preserve its uniformity of shape.

Eighth. Continuous (and rapid) firing without requiring the barrel to be cleaned.

Ninth. Preservation of powder. The casing as an insulator prevents galvanic action between the metallic shell and balls which chemical action in time would deteriorate the powder.

Tenth. The casings are made, the balls placed and secured firmly therein, separate from the metallic shells and can be transported in bulk or otherwise without injury and attached to the loaded metallic powder case when desirable (or at reloading of shells) conveniently.

Eleventh. This multiball cartridge is readily distinguished by touch or sight, from the single-ball cartridge.

(B.)

Description of Merwin, Hulbert & Co.'s multiball cartridge for the service rifle. (See Plate XLI.)

Weight of powder charge .... grains..	52
Number of balls	3
Diameter of balls	0″.424
Weight of balls (each) .... grains..	108.66
Total weight of lead .... grains..	326

The charge is inclosed in a copper cartridge case of service dimensions.

The three balls are inclosed in a strong casing of paper lubricated with a mixture of paraffine and beeswax, making of them a single piece.

Fig. 2. The paper is saturated with the lubricant. The case is crimped at the base to hold the balls in place; the longitudinal cuts *a a*, Fig. 2, are made through the case to facilitate rupture after it has left the piece. (A light coating of shellac covered the portion of the case that projects from the shell in some of the cartridges presented. with a view to protection of the cartridges from atmospheric influences.) Lubricant is placed in the recesses (corresponding to cannelures), where the balls come in contact.

Plate XLI, Fig. 1, represents the cartridge complete, full size.

Fig. 2, the paper case in which the balls are inclosed.

Fig. 3, a single ball.

The multiball cartridge for the revolver.

Weight of powder charge .... grains..	22
Number of balls (1 ogival and 2 spherical segments)	3
Diameter of balls	0″.424
Length of ogival bullet	0″.39
Altitude of segments	0″.236
Weight of ogival bullet .... grains..	111
Weight of segments (each) .... grains .	82
Total weight of lead .... grains..	275

The charge is inclosed in a copper cartridge case, of service dimensions. The paper casing for the bullets is like that for the rifle. The ogival has a flat base, and the bases of the segments fit to this and to each other. Lubricant is placed in the recesses and about their junctions.

Plate XLI, Fig. 4, represents the cartridge complete, full size.

Fig. 5, the ogival or forward bullet.

Fig. 6, the segment bullet.

(C.)

Record of firing for penetration with Merwin, Hulbert & Co.'s multiball cartridge for pistol.

25 YARDS.

Hits.	Penetration.	Remarks.	
	"		
1	1.50	Segment ..	Three shots (3 balls each) fired from Colt's revolver at butt 6' × 6'.
2	1.75	Ogival	
3	1.25	Segment ...	
4	1.75	Ogival	
5	1.50	Segment ...	
6	1.00	Segment ...	
7	1.25	Segment ...	
8	1.75	Ogival	
9	1.25	Segment ...	

50 YARDS.

Hits.	Penetration.	Remarks.	
	"		
1	1.25	Segment ...	Three shots (3 balls each) fired from Colt's revolver at butt 6' × 6'.
2	1.00	Segment ...	
3	1.125	Segment ...	
4	1.00	Segment ...	
5	0.875	Segment ...	
6	1.75	Ogival	
7	1.75	Ogival	
8	....	Struck in joint; not taken.	

1 shot missed the butt.

75 YARDS.

Hits.	Penetration.	Remarks.	
	"		
1	0.75	Segment ...	Nine shots (3 balls each) fired from Colt's revolver at butt 6' × 6'.
2	1.25	Ogival	
3	1.00	Ogival	
4	0.625	Segment ...	
5	0.250	Segment ...	
6	1.00	Ogival	
7	.875	Segment ...	
8	1.00	Ogival	
9	....	Struck in joint; not taken.	
0	....	Struck in joint; not taken.	

17 shots missed the butt.

(D.)

List of experiments adopted for the trial firing of Merwin, Hulbert & Co.'s multiball cartridge for the service rifle and revolver.

ACCURACY AND DISPERSION FOR THE RIFLE MULTIBALL CARTRIDGE.

Ten rounds to be fired from the Springfield rifle and carbine, each, at ranges of 50, 100, 150, and 200 yards. Target record to be made after each single shot.

PENETRATION.

Five rounds to be fired as above at a pine butt 6 feet square.

Penetration and number of hits to be recorded between each series of firings. If necessary, the number of rounds to be increased to obtain sufficient hits to determine the mean penetration.

ACCURACY AND DISPERSION FOR THE REVOLVER MULTIBALL CARTRIDGE.

Same as for the rifle, except that Colt's revolver to be used at ranges of 25, 50, and 75 yards.

PENETRATION.

Same as above, except that three shots to be fired in the first instance.

MERWIN, HULBERT & Co's MULTIBALL CARTRIDGE.

FOR THE SERVICE RIFLE.

Fig. 1.

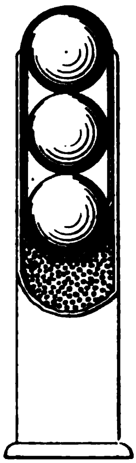


Fig. 2.

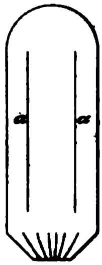


Fig. 3.

Legend.

Weight of Powder charge,	*52 grains.*
Number of Balls in each Cartridge,	*3.*
Diameter of Balls,	*0."424.*
Weight of each Ball,	*108.66 grains.*
Total Weight of Lead,	*326 grains.*

FOR THE REVOLVER.

Fig. 4.

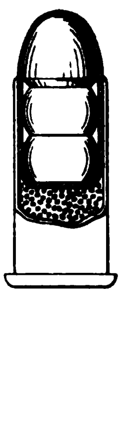


Fig. 5.

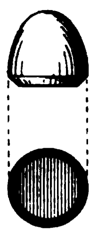


Fig. 6.

Legend.

Weight of Powder charge,	*22 grains.*
No. of Balls, (1 Ogival & 2 Sph l segments)	*3.*
Diameter of Balls,	*0."424.*
Length of Ogival Bullet,	*0."39.*
Altitude of Segments,	*0."236.*
Weight of Ogival Bullet,	*111 grains.*
do. " Segments, (each)	*82 do.*
Total Weight of Lead,	*275 do.*

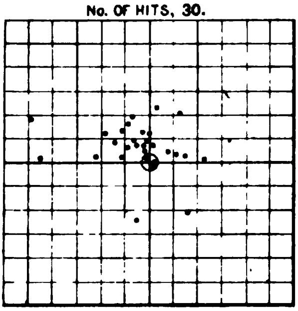
PLOTS OF 10 SHOTS (3 BALL CARTRIDGES) FIRED AT TARGETS 12 Ft. SQUARE.

POINT OF AIM CENTER.

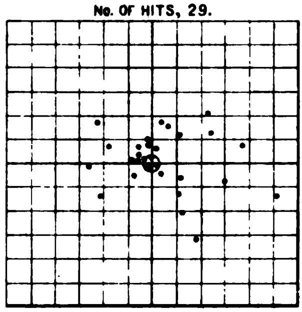
RIFLE. | **CARBINE.**

At 50 Yards.

No. of Hits, 30.

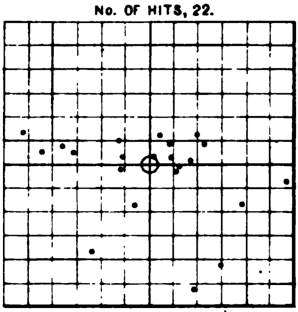


No. of Hits, 29.

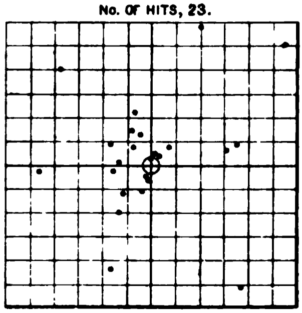


At 100 Yards.

No. of Hits, 22.

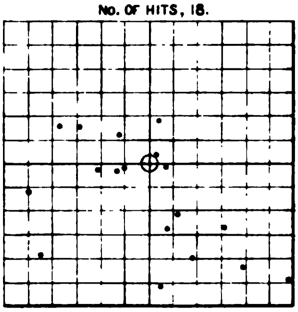


No. of Hits, 23.

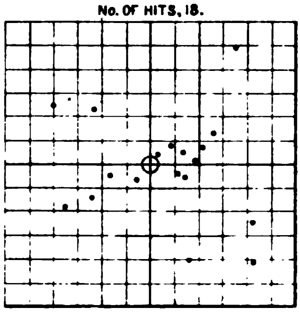


At 150 Yards.

No. of Hits, 18.

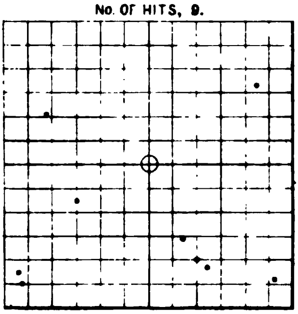


No. of Hits, 18.

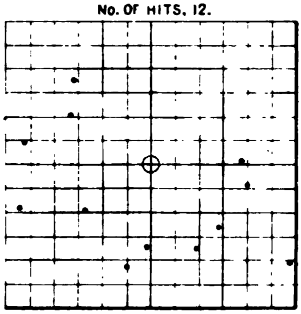


At 200 Yards.

No. of Hits, 9.



No. of Hits, 12.



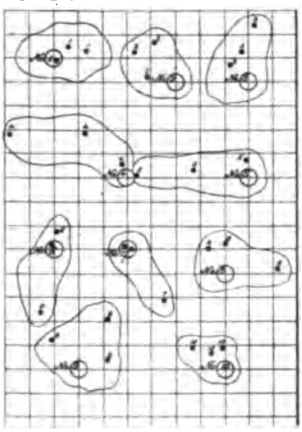
PLOTS OF SINGLE (3 BALL) CARTRIDGES, FIRED AT TARGETS 12 Ft. SQARE.

POINT OF AIM -⊕-

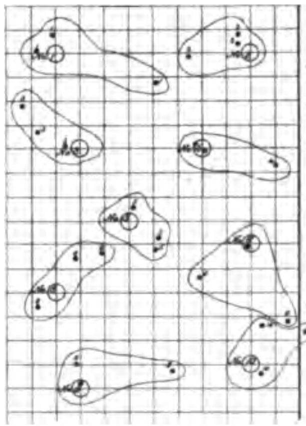
RIFLE. **CARBINE.**

AT 50 YARDS.

10 SETS OF THREE FROM 10 SHOTS.



9 SETS OF THREE FROM 10 SHOTS.



(No. 7 incomplete. Not plotted.)

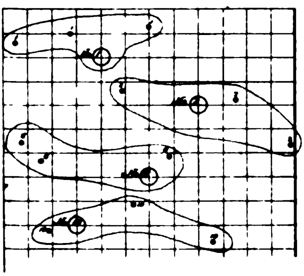
RIFLE AND CARBINE COMPARED.

RIFLE. **CARBINE.**

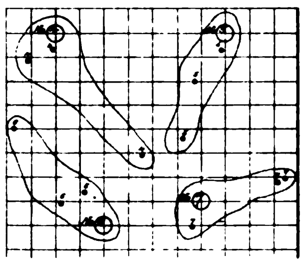
AT 100 YARDS.

4 SETS OF THREE FROM 10 SHOTS.

(Nos. 3,4,5,7,8 & 9 incomplete.)



4 SETS OF THREE FROM 10 SHOTS.

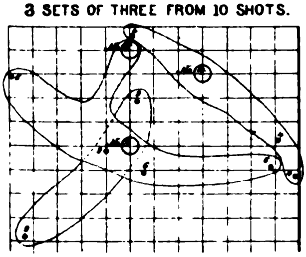


(Nos. 1,2,3,8,9 & 10 incomplete.)

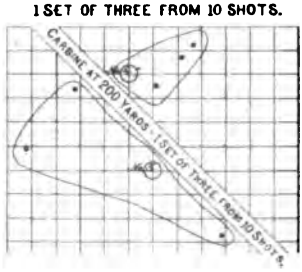
AT 150 YARDS.

3 SETS OF THREE FROM 10 SHOTS.

(Nos. 1,2,3,5,7,8 & 10 incomplete.)



1 SET OF THREE FROM 10 SHOTS.

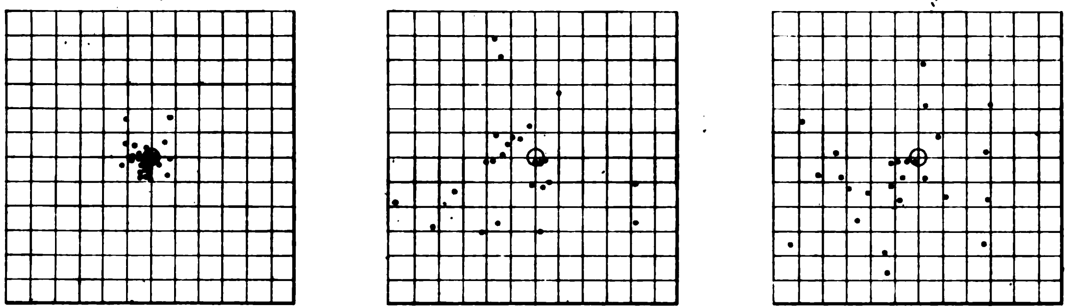


(All incomplete except No. 4.)

Note. *Rifle failed to make complete set at 200 yards.*

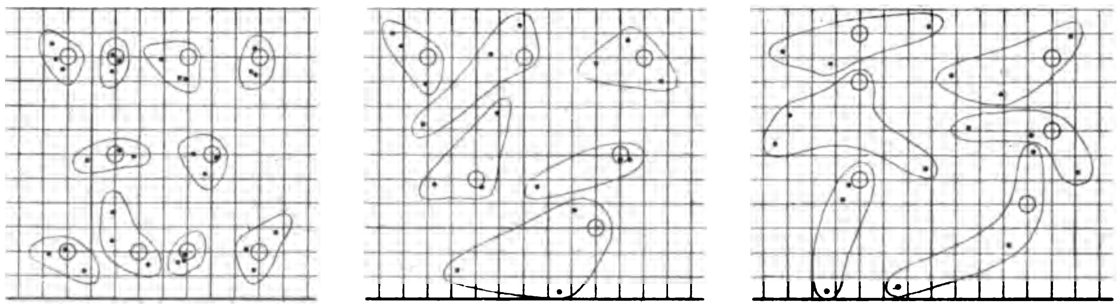
PLOTS OF 10 SHOTS (3 BALL CARTRIDGES) FIRED FROM COLT'S REVOLVER AT TARGETS 12 Ft. SQUARE. POINT OF AIM, CENTER.

AT 25 YARDS. No. OF HITS, 30. — AT 50 YARDS. No. OF HITS, 25. — AT 75 YARDS. No. OF HITS, 26.



PLOTS OF SINGLE (3 BALL) SHOTS, SHOWING TARGETS (ABOVE) SEGREGATED. POINT OF AIM, ⌖

AT 25 YARDS. 10 SETS OF THREE FROM 10 SHOTS. — AT 50 YARDS. 6 SETS OF THREE FROM 10 SHOTS. — AT 75 YARDS. 6 SETS OF THREE FROM 10 SHOTS.



(4 remaining sets incomplete.) (4 remaining sets incomplete.)

APPENDIX X.

REPORT ON RANGE FINDERS.

Capt. F. H. PHIPPS, Ordnance Department.

(Six plates.)

FIELD RANGE-FINDER—WATKINS.

PLATE I.

1. *Description of instrument.*

1. The instrument is double reflecting, on the principle of the ordinary sextant, but is so constructed that the near object is seen by reflection and the distant one by direct vision, thus rendering it easier and quicker to use, more particularly in hazy weather.

2. There are two patterns in the service, differing only in size and weight; that for the artillery being 10 inches long, $3\frac{3}{4}$ inches wide, and $1\frac{3}{4}$ inches deep, and weighing with its case about 5 pounds. That for the infantry, $5\frac{3}{4}$ inches long, $2\frac{1}{2}$ inches wide, and $1\frac{1}{4}$ inches deep, and weighing about $1\frac{1}{2}$ pounds.

This instrument consists of a brass rectangular box, carried, when not in use, in a leather case slung over the shoulder like an ordinary field-glass. When in use half of the cover is thrown back, thus exposing the right half of the instrument. Plate I, accompanying, shows the instrument, side elevation, cover half open; end elevation, cover half open; and plan, cover removed. In the cover is carried a key for adjusting; and in the artillery pattern a small telescope for use in taking long ranges. There are two eye-holes, V and R, fitted in the larger pattern with movable slides, so that the instrument can be used with or without the telescope; the arrows indicate the direction in which the observation is taken.

3. On a brass arm, F G, pivoting at N, is fixed a mirror, N, similar to the index-glass of an ordinary sextant. Another glass, O, corresponding with the horizon-glass of a sextant, is secured to a shorter metal arm, H I, capable of revolving round a pivot at H, and fitted at I with a steel screw. This arm plays between two steel blocks, K and L, so placed as to allow of a transverse of 45°, and is moved by the rack Q, actuated by the knob P.

By this arrangement the position of the screw I can be attached relatively to the arm H I without disturbing the total angular traverse of the mirror O, which remains constant at 45°. If then the arm H I be locked in position, so that the screw I bears against the block L, by screwing or unscrewing I the mirror O can be adjusted parallel to the index-glass N. An optically true right angle will then be secured by traversing the arm until the screw I presses against the block K. By this arrangement the instrument can be tested, and by using the key, carried in the cover, adjusted in a few moments.

4. The edge F G is fitted with a steel plate, against which bears a steel projection on the sliding collar E. This collar slides on a brass arm, C D, pivoted at C, and graduated with a scale of yards representing the different lengths of base with which the instrument can be used.

5. At the extremity of C D is a steel block, D, against which the screw

B bears. This screw is rigidly fixed to a metal cylinder, A, on which is engraved a scale of ranges. When the screw B is turned the arm C D is moved on its pivot C, and the sliding collar E, bearing against the arm F G, causes it to move on its pivot at N, thus altering the angle of inclination of the mirror N. The amount of motion of the screw B to give a definite movement to the mirror N depends on the position of the sliding collar E on the arm C D; consequently, by setting this collar to the proper graduation for the base used, the one scale of yards engraved on the cylinder A will give the range within the limits of the graduations without any calculation whatever.

6. The fittings supplied for use with the instrument are:

(*a.*) A wire cord, 18 feet long, in a leather case.

(*b.*) A steel tape, in case, for occasionally testing the cord.

(*c.*) Three steel pickets, fitted with leather disks to render them conspicuous. These are carried in leather buckets.

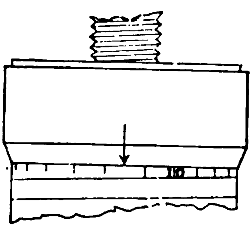
(*d.*) For mounted men two knee-halters.

7. Two men are generally employed as range-finders, though, if necessary, the service can be performed by one only.

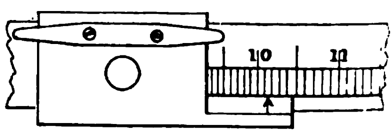
No. 1 carries the instrument slung over his shoulder like a field-glass, one picket (when mounted strapped to the saddle on the off side), steel tape in case, and knee-halter (if mounted). No. 2 carries wire cord in case, two pickets (when mounted strapped to the saddle on the off side), and knee-halter.

II.—*Manipulation of the instrument.*

1. The instrument, when in use, is most conveniently held horizontally in the left hand, back under, thumb to the left. It will be seen that the eye-holes (R V) are bored obliquely, and they should be so looked through, as shown by arrows in the plate. The numbers on the cylinder read from right to left. When using it to ascertain the length of the base A C (Fig. 3), which is, under ordinary circumstances, from 60 to 120 yards in length, the arrow-head can only point somewhere between the 600 and 12 (that is, 1,200). These numbers correspond respectively with the 6 and 12 on the scale of bases C D on the plate. If, for example, the arrow-head on the cylinder points as in Fig. 1, it would read 101½, and would be transferred and set on the scale of basis as shown in Fig. 2.



(Fig. 1.)



(Fig. 2.)

2. In reading the range on the cylinder, the numbers from 500 to 990 give the actual range in yards, while those from 10 to 50, that is, for the remainder of the scale, express hundreds of yards. Thus the arrow-head pointing to 850 would indicate a range of 850 yards, and when pointing to 23 would indicate a range of 2,300 yards.

3. As No. 2 does not necessarily know what object No. 1 is taking, he, in the first instance, plants only the picket A and unrolls his measuring cord. As soon as he sees No. 1 nearly in position he turns the top of

the picket A until one of the cross lines cut on it points to No. 1, and runs the cord out in the direction of the other line, thus making C A B roughly a right angle.

When No. 1 takes the range by himself he lines the picket B slightly to the right of the object, the shorter the range the more to the right. A good rule is to run the tape out in line with the object, and for a range of 1,000 yards plant the picket B a full pace to the left. For other ranges the distance should be varied on the principle above described.

It is important that exactly the same point of the object (house, trees, &c.) should be observed from both ends of the base, and to insure this the observer should ascertain what portion of the object is visible from A (Fig. 3) before moving off to C.

III.—*Adjusting the instrument.*

The instrument will seldom require adjustment, but it should invariably be tested before commencing a day's work, and corrected if necessary.

1. Open the lid by pressing the spring S, and see that the brass cylinder is screwed up as far as it will go, thus setting the instrument to zero. Press the sliding collar E back to the stop, that is, to 6 on the scale, and move the arm I until the screw I presses against the steel block L. When in proper adjustment the mirrors O and N are now parallel, and by looking through the eye-hole V at any sharply defined vertical line, such as a pole, side of a house, &c., some distance off (a picket planted about 200 yards off can be used), two images will be seen exactly over one another, one by direct vision through the plain part of the glass O, the other by reflection in the silvered part below. If these two images do not exactly correspond and the line be broken, the instrument requires adjustment.

2. To adjust the instrument, unscrew the key, apply it to the square shoulder of the screw I, and turn until the two images are in line. Move the arm H I backward and forward several times, replace it against the block L, and see that the adjustment has been properly effected.

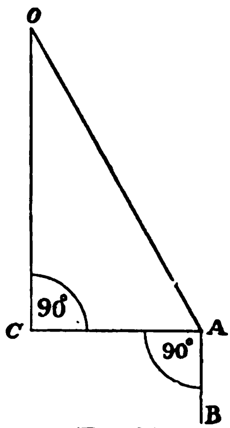
3. The length of the wire cord should be occasionally tested by means of the steel tape.

IV.—*Taking the range.*

CASE I. Where the base is between 60 and 120 yards. Suppose the distance from A to O (Fig. 3) to be required.

At "Take the range," No. 2 plants a picket with square leather head and strut at A, the flat side of head turned to the left and the strut to the rear. No. 1 notices what portion of the object he can see from A, goes off about 100 yards to the left,* at about right angles to A O. He opens the instrument, pushes the arm H I against the stop K (by moving the button P), turns instrument upside down, and looks through eyehole R at object O (Fig. 3) through the plain part of the horizon-glass O.

The picket A will appear reflected in the silvered part of the glass; should it appear to the right of the object he must retire; if to the left, he must advance, until the picket A exactly coincides with



(FIG. 3.)

* If necessary, the right angle can be laid out to the right and the range taken to the left, by reversing the operation herein detailed.

some well-defined portion of the object. He then plants the picket C between his toes, and should verify the accuracy of the observation by resting his hand on the top of the picket and looking through the instrument again; any slight error can then be rectified by forcing the head of the picket to or from him.

No. 1 has thus planted the picket C at the right angle between O and A; in other words, O C A is a right angle.

He now turns the box right side up, pushes the arm H I against the stop L (by means of the button P), faces A with C exactly between his toes, and looks through the side eye-hole V, inclining the left end of the instrument slightly downward. He will see the two pickets, A and B (which No. 2 has in the mean time planted), through the plain part of the glass O, and their reflection immediately below them. He turns the cylinder to the left, with his right hand, until he makes the reflection of the round-headed picket *exactly* coincide with the square-headed picket, and thus obtains the length of the base A C, which he reads on the cylinder. He sets the sliding collar E to the same number on the brass scale C D.

Meanwhile No. 2, as soon as he sees No. 1 plant his picket at C, lays one of the cross lines engraved on the head of the picket A on C, hooks his cord to A and stretches it to the rear in the direction given by the other line on the head of A, thus approximately setting off a right angle, A C B. He plants B at the full extent of the cord, moves off to C, ready to bring in the picket as soon as No. 1 has completed the observation, unless there are more ranges to be taken from the same spot.

No. 1 moves to A, places himself facing O, with the picket exactly between his feet, pushes the arm H I against the stop K as before, looks through the end eye-hole at the object O, which he will see through the plain part of the glass O, the reflection of the picket C being seen in the lower, or silvered, part. He turns the cylinder with his right hand until the reflection of C exactly coincides with the object, and reads off the range opposite the arrow-head on the cylinder.

When Nos. 1 and 2 are mounted, as with the artillery, the knee-halters are used to secure the horses while the observations are being taken.

CASE II. When the base is limited to under 60 yards. The operation is similar to Case I, with these exceptions:

After placing the picket C at the right angle between A and O, No. 1 sets the sliding collar to 12, before making the pickets A and B coincide with one another, by turning the cylinder. He then proceeds as before. The true range is half that finally read on the cylinder.

CASE III. When the base is limited to over 120 yards. This operation is similar to Case I, with these exceptions:

The subsidiary base A B is made 36 feet instead of 18 feet long (by hooking the cord and tape together). The true range is double that shown on the cylinder.

N. B. If the range is *under* 500 yards, proceed as in Case II. If *over* 3,000 yards, as in Case III.

V.—*To use the instrument at judging-distance drill instead of a stadiometer.*

This will be found the best way of getting accustomed to the use of the instrument, and will, moreover, be found more accurate and expeditious than the stadiometer.

The length of the base thrown out being 40 yards, set the sliding collar E so that the arrow-head is exactly on the mark 8. Press the arm H I against the block L. Reflect the flag at the left end of the thrown-

out base on to the flag at the right end by unscrewing the cylinder. Half the reading is the true range. Thus, if the index pointed to 1,010 yards, the range would be 505.

VI.—*Care of the instrument.*

As before stated, the instrument is not liable to get out of adjustment if treated with proper care. On no account should any of the small screws be taken out or meddled with, as such a proceeding is liable to throw the instrument permanently out of adjustment and to render it worse than useless.

The mirrors should be wiped occasionally with a piece of clean chamois leather or soft linen; the screw and all steel parts should be kept carefully oiled to prevent rust.

Before attempting to shut down the cover, see that the cylinder is screwed as far as it will go.

Theory of the instrument.

The conditions required for solving the range triangle C O A are that we should know the base C A and the angle C O A, the angle A C O being always a right angle. But inasmuch as we are unable to get at the point O to measure the angle, we must find a line, A D, at right angles to A C, and measure the angle D A O, which is equal to the angle C O A. This is done by taking the range with the instrument.

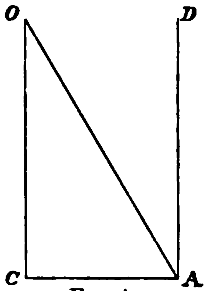


FIG. 4.

When the cylinder is set to zero (the mirrors being set at 45°), the picket C will be seen reflected in the direction D at right angles to A C. On the cylinder being revolved the image moves to the left, and is brought to coincide with the object O. The inclination of the mirrors is a measure of the angle O A D; but, as explained in the description of the instrument, the position of the sliding collar alters inclination of the mirrors, and, being set to the base, the cylinder gives the range due to that base.

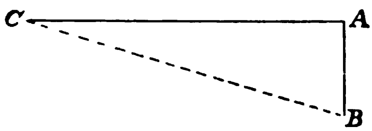


FIG. 5.

In measuring the base A C, a small range triangle, similar to O C A in the previous figures, is worked out. As we are, however, in this instance, at the station C, we can obtain the angle A C B, which A B subtends, by reflecting the picket B on to A. If, then, the sliding collar be placed at the distance A B on the base scale, the cylinder will mark the distance A C. As A B is always 6 yards, the sliding collar is, for this operation, placed at the mark 6, representing 60 yards in the range triangle. The results obtained are, therefore, ten times the true ones; thus the same scale on the cylinder does for both bases and ranges; if only in the former, we divide by ten. It is advisable, however, always to read this scale as for ranges, multiplying the base scale on the brass bar by ten, so as to avoid confusion. Thus a base of 100 yards would be read as 1,000 yards, and the sliding collar set at 10. If a tape of 10 yards be used, the same result for A C would be obtained by setting the sliding collar to the mark 10 before reflecting the image of B on to A.

Suppose O an object distant 1,000 yards, A C a base of 120 yards, and D C a base of 60 yards. The angle A O C will be double the angle D O C, and, generally, if A C = *n* D C, the angle A O C = *n* times the angle D O C.

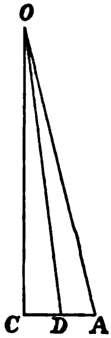


FIG. 6.

As there is only one given position of the cylinder and screw for any given range, some arrangement had to be devised by which the inclination of the mirrors might be altered, irrespective of the screw, so as to cause them to assume a greater inclination for a large base than for a small one.

This is arrived at by means of the arm C D (Plate I), with the sliding collar E bearing against the arm F G. As these two arms pivot at Nand C, it is evident that the farther the slide is away from C the greater will be the movement of the arm F G (and consequently of the mirror fixed to it) for any definite movement of the screw B.

The principle by which a right angle is obtained, when the mirrors are inclined at 45° to one another, will be found in any elementary books on surveying or optics. The fact of there being two eye-holes does not affect the principle; it was devised in order to reduce the instrument into the smallest possible limits.

The foregoing description was furnished with the instrument.

TESTS IN ENGLAND.

This instrument was tried with very satisfactory results in England by the committee on range-finding instruments, and has been adopted in that country for field purposes.

In the English tests a mean of 22 observations by two men gave 2′ 23″ as the average time required for an observation; the time varying from 1′ 50″ to 3′.

The mean error of 11 observations taken by Captain Watkins himself was 10.7 yards, or 0.48 per cent. of the mean range.

RESULTS AT SANDY HOOK.

The instrument was tested at Sandy Hook June 19 and August 22, 1879, with the following results:

	Actual.	By instrument.	Error.	Base-line.	Time.	Remarks.
	Yards.	*Yards.*	*Yards.*	*Yards.*		
1	900	910	+ 10	97¾	Not taken.	Times marked with * taken as fast as possible; in others, length of base-line walked.
2	1,000	1,025	+ 25	100	*4′ 20″	Actual time occupied in running over a base-line of 110 yards and returning, 1′ 10″.
3	1,200	1,185	− 15	123⅓	*3′ 40″	
4	1,300	1,330	+ 30	123¾	*3′ 15″	
5	1,600	1,600	None.	123⅝	*3′ 0″	
6	1,700	1,740	+ 40	118⅝	Not taken.	
7	1,500	1,450	− 50	117	"	
8	1,400	1,345	− 55	112⅓	"	
9	1,300	1,285	− 15	115	"	
10	1,100	1,100	None.	128	"	
1	800	772	− 28	60⅓	Not taken.	
2	900	968	− 32	73⅓	"	
3	1,000	984	− 16	67⅓	4′ 20″	
4	1,100	1,059	− 41	63	*3′ 43″	
5	1,300	1,289	− 11	115	5′ 13″	
6	1,400	1,362	− 38	106¾	6′ 33″	
7	1,500	1,472	− 28	115	*3′ 40″	
8	1,700	1,679	− 21	108⅓	*3′ 13″	

A mean of the seven observations taken rapidly by the same two men gave 3′ 33″ as the average time required to calculate a distance. This time exceeds that obtained in England by 1′ 10″, but this is undoubtedly due to the fact that the observations at Sandy Hook were taken by inexperienced men, who probably had not used the instrument a half dozen times previously. Again, the Sandy Hook observations were taken over a very uneven sandy beach in a hot glaring sun. It was found that the actual time occupied in getting over the base-line alone was 1′ 10″.

CONCLUSIONS.

It will be observed, in conclusion, that the instrument has really three separate operations to perform—first, to establish a right angle, then to get the length of the base-line, and finally, after returning to the initial point, to get the range.

The length of time necessary to get an observation varies with the conditions of the ground, and the accuracy of the observation will of course depend upon the skill and care of the observer as well as the conditions of the atmosphere. The advantages of this instrument are that it is light, portable, easily worked, and can be tested and adjusted in a few moments by any person of ordinary intelligence. It indicates the range directly without calculation; no vernier is used—the only graduation being the simple scales of the length of base and ranges in yards. It is cheap as compared with other range-finders, the cost being about £7.

One man can take an observation, but for convenience and rapidity two men are preferred. The accuracy of the instrument for all ordinary artillery distances, say up to 3,000 yards, is very satisfactory.

It has the drawback, however, of necessitating the use of a right angle, but this disadvantage is greatly reduced by the facility of working with different lengths of bases, the ease with which the base can be changed, and the fact that the instrument itself is used as an optical square, thus doing away with the necessity of a separate instrument.

It is believed that the conditions of the ground and atmosphere for taking accurate observations could not have been much more unfavorable than on the days when the ranges at Sandy Hook were taken.

THE BERDAN TELEMETER.

PLATE II.

Translated from the Revue d'Artillerie of October, 1877.

The Berdan range-finder, already tested in Germany in 1875 and 1876, was intended to have been submitted this year by the commission for experiments with artillery to some new tests. The attention paid this instrument by the German artillery, as well as the notoriety the name of its inventor, the American General Berdan, known for some time by his small-arm inventions, possessed, explains sufficiently the reproduction in the *Review* of the following description taken from the *Engineer*. It will be noticed elsewhere that the instrument described in the *Engineer* differs in several points from the one tested in Prussia, the inventor having produced in succession many improvements of which the English review gives no details.—*Editor of the Review.*

It is proposed with the Berdan range-finder, as with the majority of instruments intended for the same use, to determine the side of a right-angled triangle whose base is known by measuring the angle at the apex.

Let b be the base. One can measure on the side A B (Plate II, Fig. 1), a certain number of distances, of which the constant difference is m, corresponding in range to *successive notches* of the sight.

If A B $= c$ is the smallest distance, the following results: $c + m$, $c + 2m$ . . . . , and the greatest, $c + n\,m$. The angles at the apex corresponding are given by their tangents:

$$\text{tang. B} = \frac{b}{c}$$

$$\text{tang. B}_1 = \frac{b}{c + m}$$

$$\text{tang. B}_2 = \frac{b}{c + 2\,m}$$

. . . .

$$\text{tang. B}n = \frac{b}{c + n\,m}$$

One is able to measure in practice these different angles by prolonging to the rear of the point C the hypothenuse of each triangle as far as the arc of a circle described from the point C with a radius l. (Fig. 2.) We obtain in this way the points 0 . 1, 2 . . . . h and the arcs 0D, 1D, 2D — nD, or X, X_1, X_2—Xn, measuring the angles B, B_1, B_2 — Bn.

If it is desired, for example, to measure some infantry distances:*

$$C = 300 \text{ meters.}$$
$$m = 50 \text{ meters.}$$
$$c + n\,m = 1{,}600 \text{ meters.}$$

If we take $b = 2$ meters and $l = 0.4^{m}$, we have:

$$\text{tang. B} = \tfrac{2}{300} = 0.00666,\ \text{B} \doteq 22'\ 55''$$
$$\text{tang. B}_n = \tfrac{2}{1600} = 0.00125,\ \text{B}_n = 4'\ 17''$$
$$\text{angle } (\text{X} - \text{X}_n) = \text{B} - \text{B}_n = 18'\ 38''$$

Upon a circumference whose radius is 1 this angle intercepts an arc of 1118×0.000004848,† which is 0.00542; for a radius of 400 millimeters, $\text{X} - \text{X}_n = 0.00542 \times 400 = 2.168^{mm}$.

* On the supposition that the Army has a gun whose sight is graduated from 50 to 50 meters between the limits of 300 and 1,600 meters, and admitting that in firing at distances less than 300 meters the maximum ordinate of the trajectory is sufficiently small to do away with the necessity for recourse to an exact measure of the distance.

† 0.000004848 is, in decimal parts of the radius, the value of the arc of 1''.

These arcs are, moreover, sufficiently small to enable one to substitute for their lengths those of their tangents, and to form the following table without recourse to trigonometrical tables:

Distances in meters. $c_1 c+m, \ldots . c+n m$	Tangents. tang. B, $B_1, \ldots . B_n$.	Arcs. $X, X_1, X_2, \ldots . X_n$.	Differences. $X-X_1. X_1,-X_2 \ldots . X_{n-1}-X^n$.
		Millim.	*Millim.*
300	0. 006666	2. 667	0. 381
350	0. 005714	2. 286	0. 286
400	0. 005000	2. 000	0. 223
450	0. 004440	1. 777	0. 177
500	0. 004000	1. 600	0. 146
550	0. 003636	1. 454	0. 121
600	0. 003333	1. 333	0. 103
650	0. 003076	1. 230	0. 087
700	0. 002857	1. 143	0. 077
750	0. 002666	1. 066	0. 066
800	0. 002500	1. 000	0. 059
850	0. 002353	0. 941	0. 053
900	0. 002222	0. 888	0. 046
950	0. 002105	0. 842	0. 042
1, 000	0. 002000	0. 800	0. 038
1, 050	0. 001905	0. 762	0. 035
1, 100	0. 001818	0. 727	0. 032
1, 150	0. 001739	0. 695	0. 029
1, 200	0. 001666	0. 666	0. 026
1, 250	0. 001600	0. 640	0. 025
1, 300	0. 001539	0. 615	0. 022
1, 350	0. 001481	0. 593	0. 021
1, 400	0. 001428	0. 572	0. 020
1, 450	0. 001380	0. 552	0. 019
1, 500	0. 001333	0. 533	0. 017
1, 550	0. 001290	0. 516	0. 016
1, 600	0. 001250	0. 500	
			2. 167

One sees definitely that while rapidly measuring the arcs X, X_1, X_2, the corresponding distance will be at the same time determined.

Among instruments already known a great number measure, in the same way, angles by a single observation, unfortunately too long to be practically possible on the field of battle. The essential conditions are great rapidity and accuracy in connection with the graduation of the sight.

The range-finder invented by General Berdan satisfies these conditions by reason of the advantages which it presents. So far it does not seem to be objected to in Germany, where it is very much appreciated, either by its net cost (about 25,000 francs) or by its large size, which it owes in part to its two telescopes, astronomical instruments of great power, about 5 feet long ($1^m.52$), and provided with object-glasses 4 inches ($0^m.10$) in diameter. Some improvements in details have been made in it, however, which have not so far been made public. The apparatus consists essentially of two telescopes, connected by a fixed base, one of which can be moved without altering the length of the base. This displacement can be measured by a micrometer which gives immediately the distance on the scale when the pointing of the second telescope, upon the same point of the object at which the first one is directed, is completed. The micrometer screw which produces and measures the displacement of the movable telescope has a movement equal to the total arc $X-X_n$. It is provided with a large head or drum, the circumference of which is divided in n parts proportionately to the arcs $X-X_1$, $X-X_2 \ldots \ldots \ldots X_{n1}-X_n$. Each division corresponds, therefore, to one of the distances c, $c+m$, $c+2m \ldots \ldots \ldots c+nm$.

The only precaution to be taken is to give to the head of the screw a

sufficiently large radius that the division of the scale nearest $n-1$ and n may be sufficiently distinct. Fig. 3 is a plan of the apparatus. Fig. 4 is a vertical section through its length; the two ends of the cover are turned back and the instrument arranged for the operation. Fig. 5 shows the box closed for transportation. Figs. 6, 7, 8, 9, 10, and 11 represent on a larger scale the principal parts of the apparatus. These, of which it is proper to first speak, are the two telescopes A and B, of a construction as perfect as possible for an optical instrument; the right one, B, remaining fixed during the operation, while the other, A, can be turned horizontally around pivots a_1 a_2 placed at the forward part.

The two telescopes are connected by a rigid system of stems or tubes, C′ C′; one bar or tube, L, having a parabolic profile and a section in the form of a cross, by two cross-pieces, *f g*, and four collars, *b c d e*. The horizontal bar C, which serves as the axis of rotation of the system of the two telescopes, is supported by two sleeves, D and E, and secured by the collars, which prevent the displacement of the whole in the direction of its length. The sleeve D, in which the left end of the axis C is able to turn horizontally, can itself turn on the vertical pivot *h* (Fig. 6). It is thus that this pivot serves to center the displacement of the sleeve E and of the whole system. The lower part of the support of the sleeve E is guided upon the portion of the circumference I I, described about the pivot *h* as a center; it rests on the arc I I, through three small rollers, 2 2 (Figs. 9 and 11), and can be secured there by means of the pressure-screw Z. To this part of the support is secured a screw, L (Fig. 9), turning in a screw-nut, *k*, and acting upon the upper movable part of the support H, against the lower part of which the screw-nut *k* is supported. The upper part of the support H is sustained from the opposite side by the head N of the spiral spring R_2, contained in the muff M; two rollers facilitate the movement, and the accurate pointing of the telescope B is thus obtained. The latter is able, however, to turn around a horizontal axis placed at the collar *d*; this displacement is regulated by the two screws K connected with the collar *e*, and permits the adjustment of the horizontal threads of the two telescopes.

The whole system has thus a vertical movement around the axis C C, together with a horizontal movement around the pivot *h*. The two telescopes A and B are thus moved at the same time and to the same extent horizontally and vertically. This simultaneous movement is of great importance, as much so for rapidity and exactness of the observations, as for simplicity of construction of the instrument.

In addition to this the telescope A, by an independent movement, is able to turn around the pivot a_1 a_2 placed at its forward part. Each telescope has an eye-glass moved by a rack and pinion for large and small distances. The principal point of the operation is to direct the vertical thread of the telescope B upon some part of the fixed object whose distance is to be measured, and then to direct the vertical thread of A exactly upon the same point.

If the two lines of sight were adjusted before the commencement of these operations so as to intersect exactly at the shortest distances, the arc described by the telescope A around a_1 a_2 will indicate the distance sought.

The measure of this arc can be given by a differential screw, or by a simple micrometer screw, as shown in the drawing. The spiral spring R_1 (Fig. 7) preserves the contact of a steel point, fixed to the telescope A, against a steel plate which terminates the micrometric screw S. The latter is secured to the cross-bar *f*, but in such a way as to permit the

necessary displacement in order to adjust the instrument to the shortest distance.

The dimensions of the drum T correspond to the extremities of the arcs $x, x_{.}, \ldots x_n$, and consequently to the distances to be measured; an index, U, showing immediately in each case, by a simple reading, as soon as the telescope A is at rest, the distance sought. The divisions run from 50 to 50 meters, as those of the sights of small arms and of cannon. The instrument can be transported by two men, the box having handles like a hand-barrow, or it can be placed on a wagon which can be attached to an artillery caisson.

To fix it in position it is sufficient to drop the hinged legs, which take an oblique direction, as shown in Fig. 4. The two ends of the box, secured by the hinges x x, are then turned back. The vertical thread of B is pointed on the edge of an object placed at 300 meters, and the telescope A adjusted in the direction of the same point; then the horizontal threads are made to correspond by moving the screw k on the collar e (Figs. 9 and 10). Thus adjusted the apparatus is ready for service: first, the telescope B is pointed upon the object whose distance is to be measured, then the telescope A, by turning the micrometric screw; the coincidence obtained, the index U indicates the distance sought. The instrument represents a base of 2 meters; it measures and marks distances from 300 meters to 1,800 meters to about 25 meters, and up to 3,000 meters to 50 meters.*

The dimensions should change with the range of the arms with which the firing is made. About 10 seconds is necessary to arrange the instrument on the field of battle. The measure of each distance requires from 10 to 15 seconds. The arrangement above described is that which gives the best results; this can be varied, however, by keeping the micrometric apparatus in the condition shown above.

The following systems have been tried to measure the angle described by the telescope A around a_1 a_2: 1st. A circular disk provided with a screw, each turn of which corresponds in length to one of the distances to be measured; the ends will form a spiral; the disk has connected with it a turning drum, the upper face of which is graduated horizontally. 2d. An eccentric disk acting against a small roller attached to the telescope A; the eccentricity is equal to the largest arc described; the disk is graduated upon its plane face. 3d. A wedge which works between a small roller attached to the telescope A and a fixed slide-bar or guide. The employment of the wedge has given measurements sufficiently exact and easy.

The micrometer, however, represented in Figs. 6 and 7 appears preferable as easier to manage without danger of deranging the pointing. Any one of these micrometric arrangements can be equally well applied to a telemeter composed of two telescopes connected in a fixed and unchangeable manner. But if such an arrangement be adopted, in pointing the second telescope the first one is carried along with it, in consequence of which the verification of the initial direction is prevented. It is then a serious inconvenience which is avoided in the instrument the description of which has been given.

Extract from the *Engineer*, by

P. DOMBRE,
Captain of Artillery.

* Recent improvements permit, it is said, the measuring of distances as high as 6,000 meters, the error in estimating committed being less than the average error in range of artillery now in use.

EXPERIMENTS IN PRUSSIA WITH THE BERDAN TELEMETER.

(*Translated from the Revue d'Artillerie of April*, 1878.)

This telemeter was described in the October number of 1877 of the *Revue d'Artillerie*, from an article in the *Engineer*.

The model tested in Prussia is a little different from the one previously described, but the geometrical principles and its general arrangements are the same.

The instrument consists externally of a movable box 4 meters long, $1^{m}.52$ wide, and about $0^{m}.30$ high, which is transported on another box mounted on four wheels.

From experiments made at Mariendorf, near Berlin, on the 8th of March last, in the presence of delegates and military attachés of high rank, it appears that the rapidity of putting in position and measuring is very great, since the whole of the two operations only required from 15 to 20 seconds; in spite of unfavorable weather the measurements made were extremely precise. At 1,573 meters there was no difference between the exact and the instrument measurements; at 2,194 meters there was only an error of 1 meter.

Later experiments, made on the 19th of March, had for their object the proving of the solidity of the instrument and the measurement of the distances of moving objects. An object at 1,640 meters was chosen, and the instrument with four horses attached was made to cross a trench four times. The telemeter stood the test perfectly, because, as proving it, in spite of these shocks it measured a distance of 1,640 to 1,641 meters. Different persons then measured the distance to a mounted officer who was manœuvring a company; the instrument gave from 1,550 to 1,560 meters. Afterward the distance at which the men were was taken, and the instrument indicated from 1,570 to 1,580 meters.

(*Allgemeine Militär Zeitung et National Zeitung.*)

THE IMPROVED TELEMETER, BERDAN.

(*Translated from the Revue d'Artillerie of May*, 1879.)

PLATE III.

Germany—Telemeter—Berdan.

General Berdan has recently modified his telemeter for garrison and sea-coast service, and constructed a new model intended for field and mountain artillery.

This last instrument is constructed upon the same optical principle as that which was applied in the telemeter of great range. The inventor rightly thought that his first telemeter was too heavy for field and mountain batteries, and endeavored to make this instrument lighter, more easily handled, and cheaper. The telemeter represented in (Plate III) Figure 1 is the old instrument modified; it is called No. 6 in the series of General Berdan's essays. In this model the box can be turned in all directions independently of the wagon.

The instrument has a fixed base of 4 meters; two telescopes of $1^{m}.50$, with object-glasses 90^{mm} in diameter, and a reckoner which indicates directly distances up to 10,000 meters. The author asserts that it only

takes 30 seconds on an average to estimate distances, and that the errors of observation are less, even for movable objects, than the average error in range resulting from the precision of fire of artillery.

This instrument, although more powerful than the one described previously (*Revue d'Artillerie* of October, 1877), and more easily handled, in consequence of the rapidity with which the first telescope can be directed upon the object to be sighted, is still too cumbersome for service with field-batteries, and should be reserved for garrison and sea-coast batteries. Telemeter No. 7 (Plate III, Figures 2 and 3) is of smaller dimensions; it is quite portable. Figure 2 represents it packed up, the box and the instrument on one side of the horse and the folding-stand balancing them on the other side.

In Figure 3 the instrument is in position ready for use. It has a base of $1^{m}.33$; the telescopes are $1^{m}.12$ long, and the reckoner is graduated up to 6,000 meters. For transportation the telescopes are packed in the direction of the length of the instrument.

The power of this telemeter is one-half that of No. 6; one operation occupies about 30 seconds. The weight of No. 7 is only 70 kilometers (154 pounds), while that of No. 6 is about 1,000 kilometers (2,200 pounds). No. 7 is therefore suited to field and mountain batteries, as well as for observation on shipboard.

The inventor is now working at a telemeter for infantry. This instrument (which will be called No. 8) will be on the same plan as No. 7, but smaller and lighter. It can be carried on the field of battle by means of a hand-barrow by the pioneers charged with the observations.

General Berdan thinks that the very high price of his instrument* ought not to be considered in the choice of a telemeter, in consequence of the advantages which result from the *exact* determination of distances. It is impossible, in his opinion, to construct a practical instrument smaller and cheaper, for he thinks it absolutely necessary to have a fixed base and a reckoner; now the fixed base being always tolerably small (4 meters at the most), involves necessarily the employment of powerful telescopes.

NOLAN'S RANGE-FINDER.

Plates IV, V, and VI.

The principal parts of Nolan's range-finder are—

1. Two instruments for measuring angles.
2. One tape-line.
3. One reckoning cylinder.

Each of the two instruments consists of two telescopes, which lie crosswise one above the other under an angle of about 90°; the smaller of the two has a long arm, with a vernier at one end; to the other a sector is fastened, which is divided up into degrees.

By means of a screw, an angle of about 20° can be described by the upper or smaller telescope.

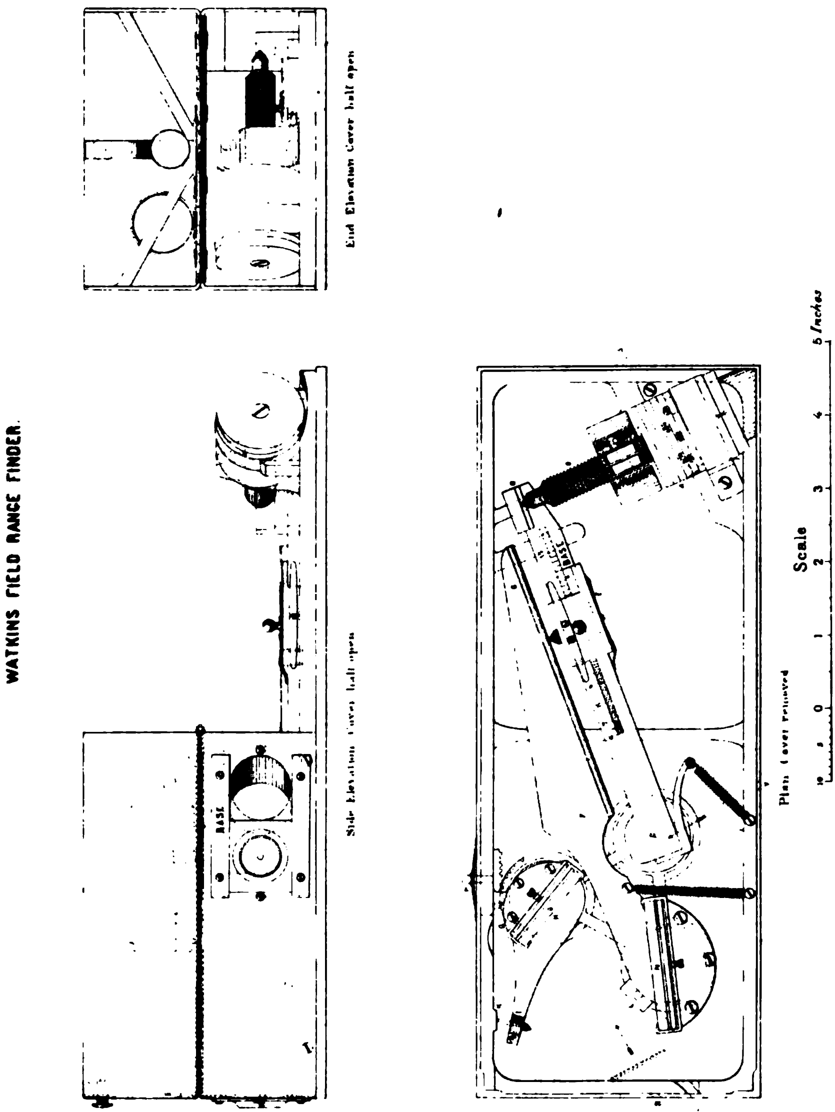
The reckoning cylinder consists of a solid body and two rotating rings. The lower ring and the lower edge of the body are divided into

	Francs.
*Telemeter No. 6, with carriage	25,000
Telemeter No. 6, without carriage	20,000
Telemeter No. 7	5,000
Telemeter No. 8	3,750

100 equal parts. On the upper ring are the logarithms of the figures, and on the upper edge of the body are the logarithms of the signs, from 6″ up to 2° 15′.

To find the range, the instruments on their tripods are arranged at the end of the assumed base-line, which is perpendicular to the range; or the instruments may be attached to the right and left guns of a battery. The long telescopes are turned toward the object whose distance is to be found; the smaller ones upon each other, and the cross-threads of each made to cover the cross-lines on the leather disk through which each small telescope points. The coincidence obtained by directing the longer telescope on the object, the two angles at the base are determined; the base-line being measured, one side and two angles of the triangle are obtained. With this data recourse is then had to the reckoning cylinder. The arrow marked "band" is set on the figure that corresponds with the distance between the instruments or base-line—say 34 yards; then set the arrow on the lower ring on the figure corresponding with the angle found through the instrument—say 18°; then find the figure for the number of degrees of the other angle—say 42° on the lower ring. Just above that is the figures 60 on the other division of the lower ring; coinciding with this on the lower edge of the upper ring is the distance, 1,320 yards. The bases used are from 30 to 40 yards for a range of 3,000 yards and over.

PLATE I.



Appendix X.—Report of Chief of Ordnance, 1879.

PLATE II.

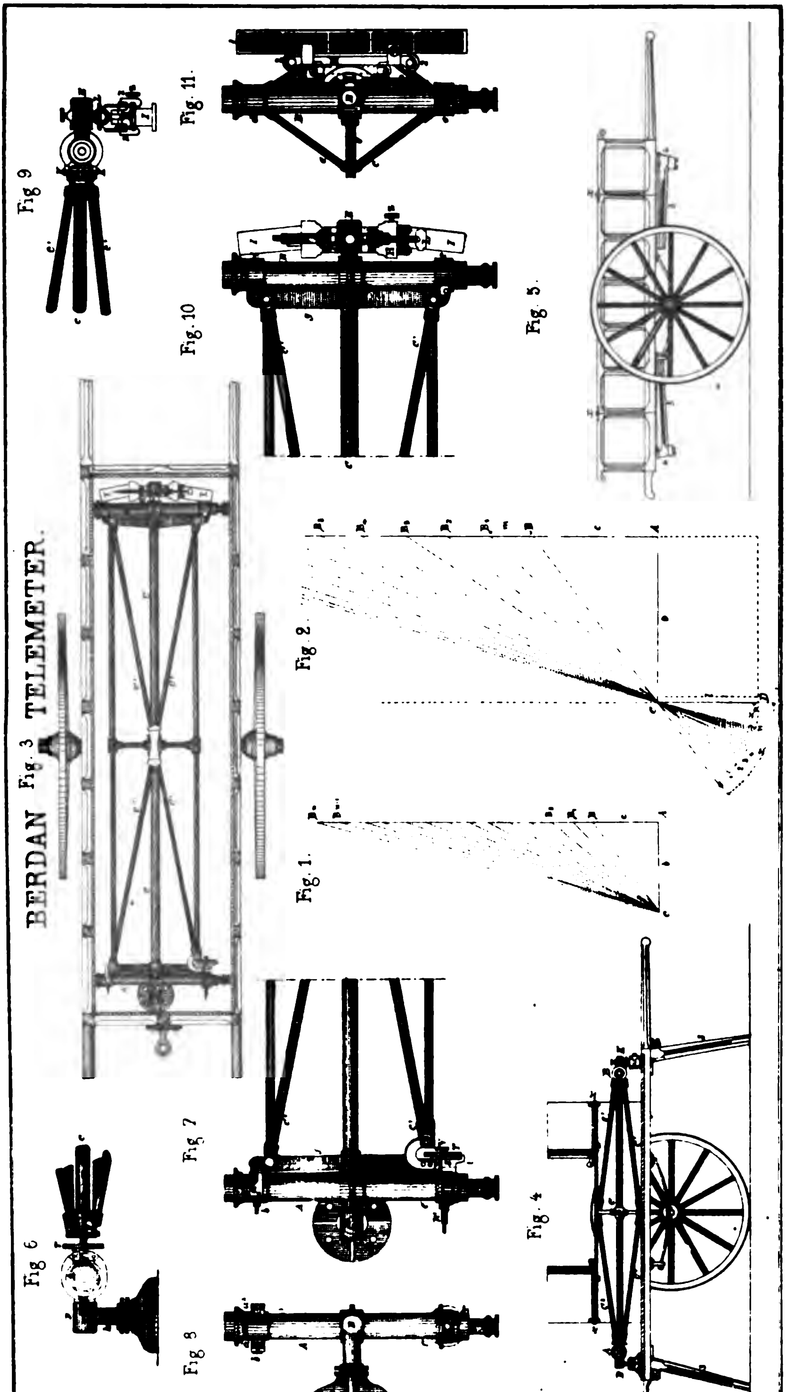

BERDAN TELEMETER.
Fig. 1.
Fig. 2.
Fig. 3
Fig. 4
Fig. 5.
Fig 6
Fig 7
Fig 8
Fig 9
Fig. 10
Fig. 11.

FIG. 1.

TELEMETER NO. 6.

GARRISON AND SEA-COAST BATTERIES.

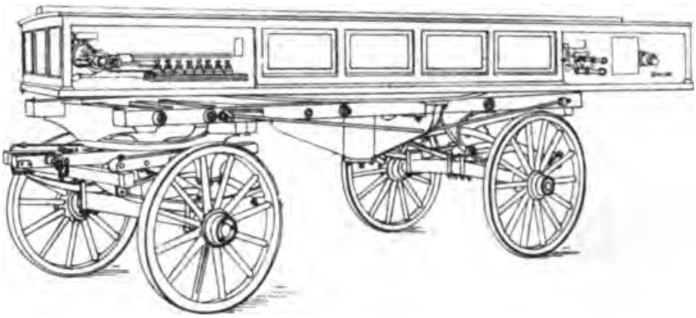


FIG. 2.

TELEMETER NO. 7.

(FIELD AND MOUNTAIN BATTERIES.) TRANSPORT.

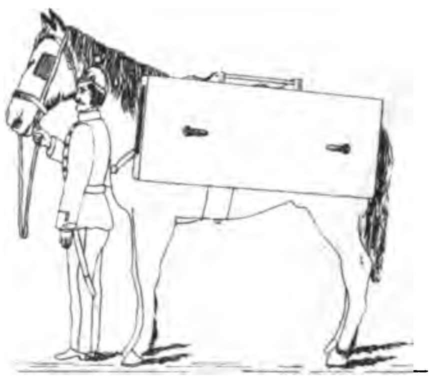


FIG. 3.

TELEMETER NO. 7.

(FIELD AND MOUNTAIN BATTERIES.) IN STATION.

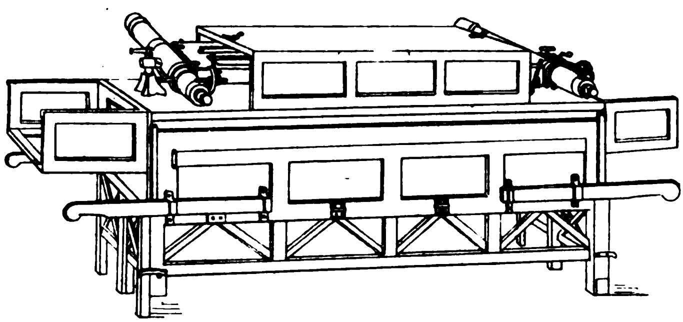
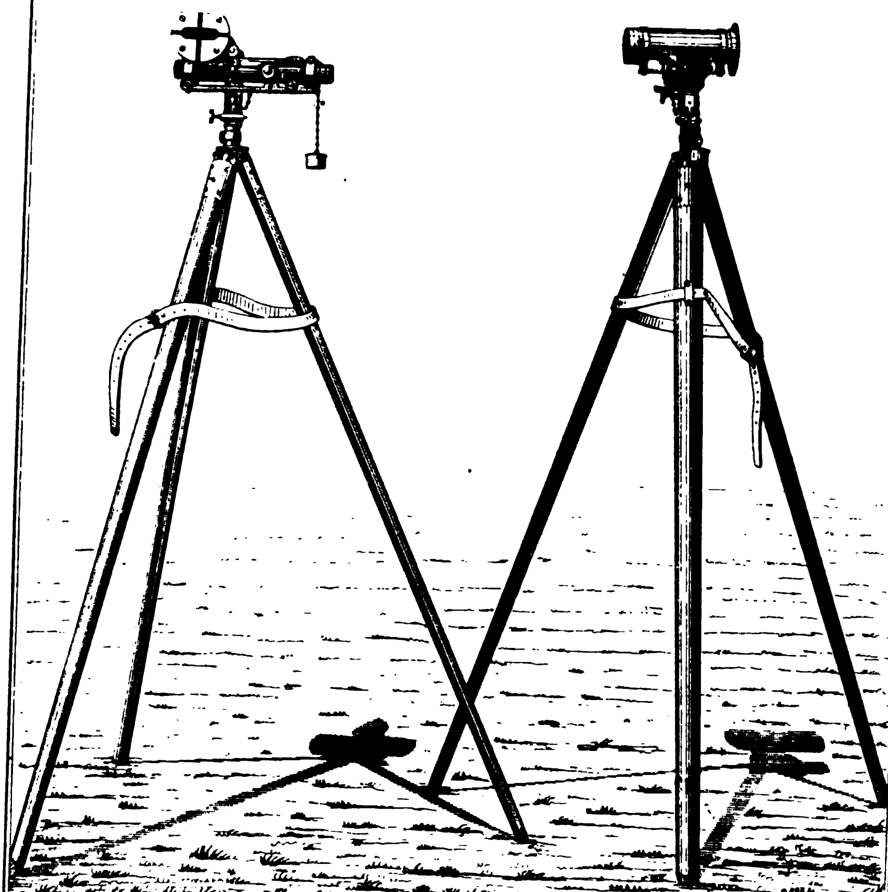


PLATE IV.

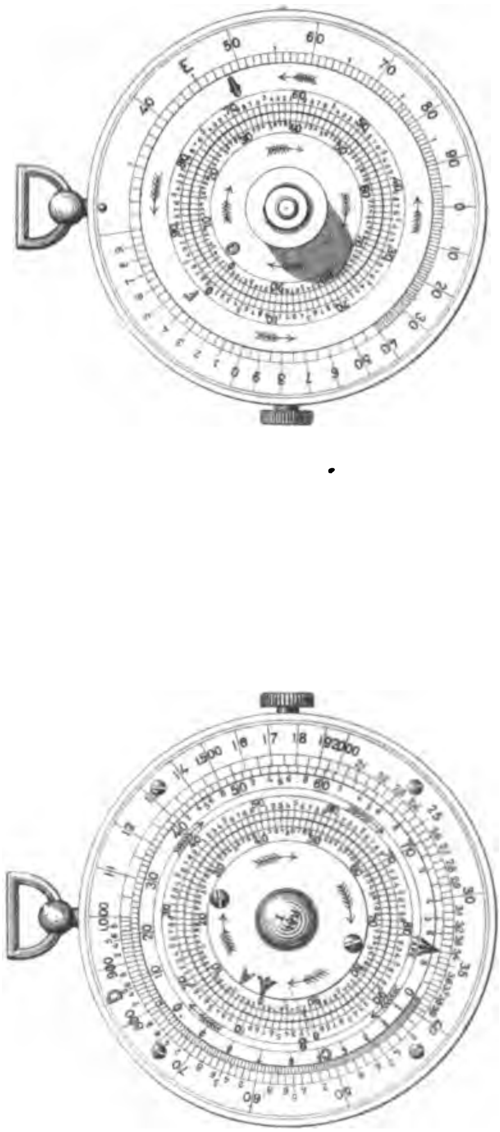
NOLAN'S RANGE FINDER.

INSTRUMENTS FOR MEASURING ANGLES.

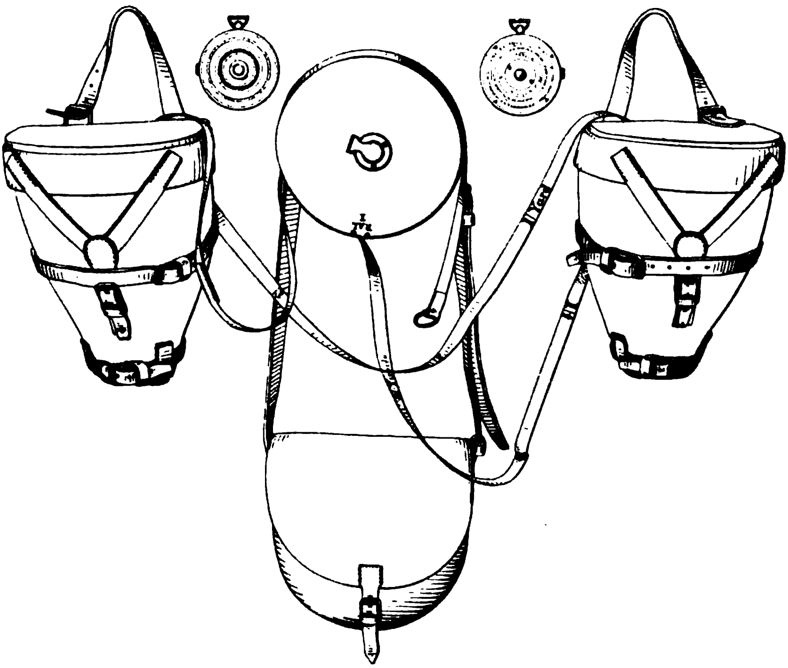


NOLAN'S RANGE FINDER.

RECKONING CYLINDER.



NOLAN'S RANGE FINDER.



APPENDIX Y.

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON THE 1ST OF OCTOBER, 1879.

Rank and name.	Duty.
BRIGADIER-GENERAL.	
STEPHEN V. BENÉT	CHIEF OF ORDNANCE.
COLONELS.	
1. P. V. Hagner, brevet brigadier general.	Commanding the Watervliet Arsenal.
2. T. T. S. Laidley, brevet	Commanding the Watertown Arsenal.
3. J. G. Benton, brevet	Commanding the National Armory.
LIEUTENANT-COLONELS.	
1. J. McAllister, brevet colonel	Commanding the Benicia Arsenal.
2. S. Crispin, brevet colonel	Commanding the Ordnance Agency; President of the Ordnance Board, and Constructor of Ordnance.
3. T. G. Baylor, brevet colonel	Commanding the New York Arsenal, and member of the Ordnance Board.
4 J. M. Whittemore	Commanding the Frankford Arsenal.
MAJORS.	
1. A. R. Buffington, brevet	Commanding the Allegheny Arsenal.
2. D. W. Flagler, bvt. lieutenant-colonel	Commanding the Rock Island Arsenal.
3. A. Mordecai, brevet lieutenant-colonel	Instructor of Ordnance and Gunnery, U. S. Military Academy.
4. S. C. Lyford, brevet lieutenant-colonel	On duty in the office of the Chief of Ordnance.
5. F. H. Parker, brevet	Commanding the Atlantic Powder Depot.
6. J. P. Farley	Commanding the Kennebec Arsenal.
7. L. S. Babbitt	Commanding the Fort Monroe Arsenal.
8. W. A. Marye	Commanding the Augusta Arsenal.
9. I. Arnold, jr	Commanding the Indianapolis Arsenal.
10. C. Comly	Commanding the San Antonio Arsenal, and Chief Ordnance Officer Department of Texas.
CAPTAINS.	
1. J. H. Rollins, brevet*	Assistant, Watervliet Arsenal (on sick leave of absence for one year from May 1, 1879.)
2. J. R. McGinness, brevet major	Commanding the Saint Louis Powder Depot.
3. G. W. McKee, brevet major	Commanding the Washington Arsenal.
4. F. H. Phipps, brevet	Recorder of the Ordnance Board.
5. J. W. Reilly, brevet	Chief Ordnance Officer Military Division of the Missouri.
6. J. A. Kress, brevet major	Commanding the Vancouver Arsenal, and Chief Ordnance Officer Department of the Columbia.
7. O. E. Michaelis, brevet	Chief Ordnance Officer Department of Dakota.
8. W. Prince, brevet	Sick leave of absence for one year from June 5, 1879.
9. C. E. Dutton	Secretary of the Public Land Commission, Department of the Interior.
10. J. G. Butler	Assistant, Watervliet Arsenal,
11. C. Bryant	Assistant to the Constructor of Ordnance.
12. A. L. Varney	Assistant, Watervliet Arsenal.
13. J. C. Clifford	Assistant, Rock Island Arsenal.
14. E. M. Wright	Assistant, Frankford Arsenal.
15. J. E. Greer	Assistant, National Armory.
16. J. Pitman	Assistant, Watertown Arsenal.
17. C. Shaler	Chief Ordnance Officer Department of the South.
18. H. Metcalfe	Assistant, Frankford Arsenal, and Inspector of Contract Ammunition.
19. W. S. Starring	Assistant to the Constructor of Ordnance.
20. C. S. Smith	Assistant, Ordnance Agency.
FIRST LIEUTENANTS.	
1. S. E. Blunt	Acting Assistant Professor of Mathematics, and Assistant to the Instructor of Ordnance and Gunnery, U. S. Military Academy.
2. F. Heath	Assistant, Rock Island Arsenal.

*Capt. J. H. Rollins, on account of ill-health, waived promotion to the grade of major.

Statement showing stations and duties of officers of Ordnance Department, &c.—Continued.

Rank and name.	Duty.
FIRST LIEUTENANTS—Continued.	
3. D. M. Taylor	Chief Ordnance Officer Department of the Missouri, and commanding the Fort Leavenworth Ordnance Depot.
4. D. A. Lyle	Assistant, National Armory, and member of the Board on Life-saving Apparatus, &c., under the Secretary of the Treasury.
5. J. Rockwell, jr	Assistant Instructor of Ordnance and Gunnery, Military Academy.
6. W. B. Weir	Commanding the Cheyenne Ordnance Depot.
7. J. C. Ayres	Commanding the Fort Abraham Lincoln Ordnance Depot.
8. M. W. Lyon	Assistant, Benicia Arsenal.
9. C. W. Whipple	Assistant to the Constructor of Ordnance.
10. A. H. Russell	Assistant, Watertown Arsenal.
11. R. Birnie, jr	Assistant, National Armory.
12. I. MacNutt	Assistant, Rock Island Arsenal.
13. C. C. Morrison	Assistant, National Armory.
14. F. Baker	Assistant, Rock Island Arsenal.
15. O. B. Mitcham	Acting Assistant Professor of the French Language and English Studies.
16. H. D. Borup	Assistant, Frankford Arsenal.
ORDNANCE STOREKEEPERS.	
(Not in the line of promotion.)	
E. Ingersoll, major	On duty, National Armory.
W. R. Shoemaker, captain	In charge, Fort Union Arsenal.
B. H. Gilbreth, captain	On sick leave of absence.
E. D. Ellsworth, captain	On sick leave of absence.
W. Adams, captain	On duty, Fort Monroe Arsenal.
A. S. M. Morgan, captain	On duty, Allegheny Arsenal.
W. H. Rexford, captain	On temporary duty, Benicia Arsenal.
F. Whyte, captain	On duty, Washington Arsenal.
D. J. Young, captain	On duty, Watervliet Arsenal.
M. J. Grealish, captain	On duty, Augusta Arsenal.

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